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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 64

CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

BY

CHARLES D. WALCOTT

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

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CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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The references in **heavy-faced** type refer to the locality numbers and the pages upon which the genera and species are described and figured.

* By error printed "Glacial" in text instead of Glacier National Park.

* By type error, spelled *continua* in text.

* By type error, spelled *continua* in text.

* Text should read *Saratogia,* instead of *Lonchocephalus,* p. 204.

* By type error listed as *Drepanura ketteleri* in the second reference.

* By oversight, correlated with the Upper Cambrian Maryville limestone, in second reference.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 64, NUMBER 1

CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 1.— THE CAMBRIAN FAUNAS OF EASTERN ASIA

(WITH PLATES 1 TO 3)

BY
CHARLES D. WALCOTT

(PUBLICATION 2263)

CITY OF WASHINGTON
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III

No. 1.—THE CAMBRIAN FAUNAS OF EASTERN ASIA

By CHARLES D. WALCOTT

(With Plates 1 to 3)

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ILLUSTRATIONS

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INTRODUCTION

A memoir on "The Cambrian Faunas of China" was published by the Carnegie Institution of Washington in 1913 as a quarto volume illustrated by 9 text figures and 24 plates containing 946 figures of fossils. The volume was issued in an edition of 750 copies, of which 308 were sent to libraries, 29 to individuals, and the remainder held for sale at $5.00 per volume.

I find there is a desire on the part of teachers and students of geology and Cambrian paleontology that the general results of the study of the Cambrian faunas of eastern Asia be put in such form as to make them readily accessible for consultation without recourse to the memoir. With this in view, and in order to place the data contained in the introduction in the hands of many of the younger geologists and students who do not have access to the memoir, permission was obtained from the Carnegie Institution to republish the Introduction. Slight additions have been made to it with reference to the work on Cambrian geology and paleontology by M. J. Deprat and M. H. Mansuy[1] in Indo-China, and on the boundary line between the Cambrian and post-Cambrian formations.

[1] Mém. du Service géol. de l'Indo-Chine, Vol. I, 1912, Étude géologique du Yun-Nan oriental, Pt. 1, Géologie géneral; Pt. 2, Paléontologie.

In a preliminary paper, published in 1911, illustrations were given of a number of new genera and species of the Cambrian fauna of China.[1] All of the types of the genera and species described in the memoir have been recorded in the Catalogue of the United States National Museum and are deposited in the collections of the Museum.[2]

PREFATORY OBSERVATIONS

When looking over the descriptions of the stratigraphic sections of the Paleozoic formations of China by Baron Ferdinand von Richthofen,[3] and their contained Cambrian fossils described by Dr. W. Dames,[4] from Liau-tung, and Dr. Emanuel Kayser,[5] I was impressed with the necessity of having the stratigraphic sections studied in detail, and extensive collections of fossils made, in order that comparisons of value might be instituted between the Cambrian sections and faunas of the western portion of North America and the Paleozoic sections and their contained faunas in eastern Asia. This project was held in abeyance for eighteen years, and had it not been for the support of the Carnegie Institution of Washington it might not have been consummated.

Dr. Bailey Willis has given, in the preface of volume 1, part 1, of "Research in China," 1907, a brief statement of the events that led to the sending of an expedition in his charge and the securing of data and collections by him and his associate geologist, Mr. Eliot Blackwelder.

On the return of Messrs. Willis and Blackwelder, I made a preliminary study of the Cambrian fossils and submitted to them the results of the study bearing on the interpretation of the various

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[1] Cambrian Faunas of China, Smithsonian Misc. Coll., Cambrian Geology and Paleontology, Vol. 57, 1911, No. 4.

[2] Other papers that I have published on the Cambrian faunas of eastern Asia are as follows:

The Cambrian fauna of India, Proc. Washington Acad. Sci., Vol. 7, 1905, pp. 251-256.

Cambrian faunas of China, Proc. U. S. National Museum, Vol. 29, 1905, pp. 1-106.

Idem, Vol. 30, 1906, pp. 563-595.

[3] China, by Baron von Richthofen, 1882, Vol. 2, Das Nordliche China.

[4] China, by Baron von Richthofen, 1883, Vol. 4, Palæontologischer Theil, Cambrische Trilobiten, pp. 1-33.

[5] Idem, pp. 34-36.

geological sections in which the fossils occurred. These were included in their description and discussion of the stratigraphy of Shan-tung, Shan-si, and Shen-si. Mr. Blackwelder also made a rapid reconnaissance of the southwestern portion of the province of Liau-tung, Manchuria, and identified certain Cambrian formations, but did not find any fossils.

From the collections made by Baron von Richthofen, it was evident that a considerable Cambrian fauna existed in the western part of Liau-tung, so I delayed final publication of the description and discussion of the Cambrian collections made by Messrs. Willis and Blackwelder, in the hope that material could be secured from that region. Learning in the spring of 1909 that Prof. Joseph P. Iddings, of the University of Chicago, was about to visit Japan and China in connection with his study of eruptive rocks, I induced him to visit Manchuria and make a collection of Cambrian fossils for the Smithsonian Institution from the Island of Tschang-hsing-tau, east of Niang-niang-kung, in the province of Liau-tung. He was so fortunate as to secure the services of Li San, Dr. Bailey Willis's interpreter, who was also a good collector, and they obtained a large number of specimens, representing over fifty species of invertebrate fossils.

Wishing to have better illustrations of the species described by Messrs. Dames and Kayser for Baron von Richthofen, I wrote to Prof. W. Branco, Director of the Royal Geological and Paleontological Institute and Museum at Berlin, who very kindly had photographs made for me of all the specimens illustrated by Doctor Dames that could be identified in the collections.

Through the courtesy of Dr. Wilhelm Deecke, of the Geological Institute of the University of Freiburg, I have had the opportunity of studying most of the specimens from China used for illustration by Dr. Th. Lorenz.[1] This enabled me to make identifications that otherwise would have been very difficult, owing to the fragmentary character of the specimens illustrating the trilobites.

The chief results obtained from the study of the Chinese collections are the discovery of portions of the upper part of the Lower Cambrian fauna and a great development of a Middle Cambrian fauna of the same general character as that of the Cordilleran Prov-

[1] Zeitschr. deutsch. geol. Gesellsch., Vol. 58, 1906, pp. 53-108, pls. 4-6, and 55 text figs.: Beiträge zur Geologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der Provinz Schantung in China; II: Palæontologischer Teil.

ince of western North America; also an Upper Cambrian fauna comparable with that of the Cordilleran Province and the Upper Mississippi Province of the United States. The fauna of the upper zone of the Lower Cambrian was found to be of the same general type as that of the Cambrian fauna of the Salt Range of India, and we were thus enabled definitely to locate the faunal horizons in India which have heretofore been referred to Upper Cambrian and post-Cambrian formations.

Another important discovery was that of the occurrence in the Middle Cambrian of China of a fauna comparable with that of the Middle Cambrian of Mount Stephen, British Columbia, and the southern extension of the same fauna in the Middle Cambrian of Idaho, Utah, and Nevada in the United States.

The determination of the age of the Man-t'o shales affords the data by which to fix the period of Cambrian time in which the Cambrian sea transgressed over eastern and southeastern Asia, and shows that it was somewhat later than the transgression in the Siberian area now occupied by the basins of the Lena and Yenesei rivers.

A noteworthy addition to the knowledge of the Cambrian faunas was the discovery for the first time of a true cephalopod in a fauna referred to the Upper Cambrian. This is illustrated by a species of *Cyrtoceras,* which occurs in the lower part of the Ch'au-mi-tién limestone. Other details will be found in the discussion of the subfaunas and their stratigraphic and geographic distribution.

From the study of the collections described in this memoir I anticipate that a large and varied fauna will soon be found in the Cambrian formations of China. What we now have is the result of hurried and superficial collecting. Persistent search by trained collectors will undoubtedly give material comparable in extent and beauty with that of America and Europe, and add many unique genera and species to the great Cambrian fauna.

THE CAMBRIAN FAUNAS OF CHINA

HISTORICAL REVIEW

The presence of Cambrian fossils in China was first announced by Baron von Richthofen in 1883.[1] The material gathered by him was studied by Dr. E. Kayser, to whom the brachiopods were intrusted, and by Dr. W. Dames, who described the trilobites.

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[1] China, Vol. 4, Palæontologischer Theil, I. Abhand., pp. 31-33, pls. 1, 2: Cambrische Trilobiten von Liau-tung.

Doctor Kayser described and named the following brachiopods:[1] *Orthis linnarssoni*=*Eoorthis linnarssoni*; *Lingulella* sp.; *L.* sp. Of these, we have identified *Eoorthis linnarssoni* from the collections of the Carnegie Institution of Washington Expedition to China.

Doctor Dames described and named the following trilobites:[2]

Agnostus chinensis	*Anomocare nanum*
Dorypyge richthofeni	*Anomocare planum*
Conocephalites frequens	*Anomocare subcostatum*
Conocephalites quadriceps	*Liostracus megalurus*
Conocephalites subquadratus	*Liostracus talingensis*
Conocephalites typus	*? Liostracus*
Anomocare latelimbatum	*? Liostracus*
Anomocare majus	Two pygidia, gen. and sp. undt.
Anomocare minus	

The material described by Doctor Dames came from three localities in Liau-tung, as follows:

Sai-ma-ki (*in situ*):

Lingulella	*Anomocare latelimbatum*
Agnostus chinensis	*Anomocare majus*
Conocephalites frequens	*Anomocare nanum*
Conocephalites quadriceps	*Anomocare subcostatum*

Ta-ling (*loose rock in wall*):

Dorypyge richthofeni	*Anomocare minus*
Conocephalites frequens	*Anomocare nanum*
Conocephalites subquadratus	*Liostracus talingensis*
Conocephalites typus	*Liostracus* sp. ?

Wu-lo-pu (*débris slope*):

Dorypyge richthofeni	*Liostracus megalurus*
Anomocare planum	

Of the above we have identified in our collections:

Agnostus chinensis	*Conocephalites typus* = *Ptychoparia*
Dorypyge richthofeni	*Anomocare latelimbatum*
Conocephalites subquadratus = *Anomocare*	*Anomocare minus*
	Liostracus megalurus = *Anomocare*

Doctor Dames compared the Cambrian trilobites with those of Europe, America, and India, and concluded that the trilobitic fauna of Sai-ma-ki and Ta-ling was about the age of the Scandinavian Andrarum limestone and the Potsdam group of North America. He did not find any Chinese species that could be identified with

[1] China, Vol. 4, Palæontologischer Theil, pp. 34-35; Cambrische Brachiopoden von Liau-tung.

[2] Idem, pp. 7-29; Cambrische Trilobiten von Liau-tung.

those of Scandinavia and America, but the general appearance of the fauna as a whole was so similar that he considered their equal age proven. He further states that the age of the rocks containing *Dorypyge richthofeni*, from Wu-lo-pu, is probably the same as that of the Quebec group, basing this upon comparisons with species from Utah, which he referred to the genus *Dorypyge*.[1]

The collections made by the Carnegie Institution of Washington Expedition prove that *Dorypyge richthofeni* occurs in the central and upper portion of the Ch'ang-hia formation and is of Middle Cambrian age. Baron von Richthofen's means of comparison were with the fauna referred to the Quebec group which was at that time supposed to be of Lower Silurian (Ordovician) age.

Dr. C. Gottsche, in 1886, called attention to the presence of Cambrian rocks and fossils in northwestern Korea, south of Wi-wön. He published a geological section and identified *Anomocare planum* Dames, *Anomocare majus* Dames, *Dorypyge richthofeni* Dames, and *Lingulella* cf. *nathorsti* Linnarsson. He also mentions the genera *Theca, Orthis, Lingulella* (two species), *Agnostus, Conocephalites, Crepicephalus,* and *? Remopleurides,* and correlates the formation with that of the "Andrarum limestone" of Scandinavia.[2]

In 1899 M. Bergeron[3] described the following Cambrian fossils from shaly limestones collected in the province of Shan-tung, China:

Agnostus douvilléi	*Arthricocephalus chauveaui*
Olenoides leblanci	*Dicellocephalus ? sinensis*
Drepanura premesnili	*Calymmene ? sinensis*

Of the above we have identified the following from the Ku-shan shale of the section made by Mr. Blackwelder:

Agnostus douvilléi	*Dicellocephalus ? sinensis* = *Stephanocare*
Olenoides leblanci	*Calymmene ? sinensis* = *Blackwelderia*
Drepanura premesnili	

From the Cambrian formations of Siberia, Dr. Fr. Schmidt[4] described the following fossils:

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[1] China, von Richthofen, 1883, Vol. 4, Palæontologischer Theil, 1. Abhand., pp. 31-33, pls. 1, 2: Cambrische Trilobiten von Liau-tung.

[2] Gottsche, C. Sitzungsberichte der königlich preussischen Akademie der Wissenschaften zu Berlin, 1886, zw. halb-bd. (June-Dec.), pp. 865, 867: Geologische Skizze von Korea.

[3] Bull. Soc. géol. France, 3d ser., Vol. 17, 1889, Paris, Notes paléontologiques, pp. 499-516.

[4] Mélanges physiques et chimiques tirés du Bulletin de l'Académie imperiale des Sciences de St. Pétersbourg, Vol. 12, 1886, pp. 407-424: Ueber einige neue ostsibirischen Trilobiten und verwandte Thierformen.

Agnostus czekanowskii
Proetus (*Phaeton*) *slatkowskii* = *Dorypyge*
Cyphaspis sibirica = *Solenopleura*
Liostracus ? maydeli = *Anomocarella*
Anomocare pawlowskii = *Anomocarella*

This fauna was subsequently reviewed by Eduard von Toll,[1] who added the following:

Confervites primordialis Bornemann
Archæocyathus acutus Bornemann
Archæocyathus aduncus Bornemann
Archæocyathus ijizkii von Toll
Archæocyathus patulus Bornemann
Archæocyathus proskurjakowi von Toll
Archæocyathus sibiricus von Toll
Coscinocyathus calathus Bornemann
Coscinocyathus campanula Bornemann
Coscinocyathus corbicula Bornemann
Coscinocyathus dianthus Bornemann
Coscinocyathus elongatus Bornemann
Coscinocyathus irregularis von Toll
Coscinocyathus vesica Bornemann
Coscinocyathus cf. *cancellatus* Bornemann
Spirocyathus sp. undt.
Rhabdocyathus sibiricus von Toll
Protopharetra sp. undt.
Helminthoidichnites sp.
Kutorgina cingulata Billings
? Obolella chromatica Billings
Hyolithes ? sp. undt.
Microdiscus kochi von Toll
Microdiscus lenaicus von Toll
Microdiscus sp. undt.
Agnostus schmidti von Toll
? Olenellus sp. undt.
Dorypyge slatkowskii Schmidt
Ptychoparia czekanowskii von Toll = *Inouyia*
Ptychoparia meglitzkii von Toll = *Inouyia*
? Solenopleura sibirica Schmidt
Bathyuriscus howelli Walcott

In 1903 Dr. H. Monke published a paper on the Geology of Shantung and described certain "Upper Cambrian" trilobites,[2] as follows:

Agnostus koerferi
Liostracina krausei
Teinistion lansi
Teinistion sodeni
Drepanura premesnili
Drepanura ketteleri
Stephanocare richthofeni
Stephanocare sp.

Of the above, three genera and species described by me in 1905 are synonyms:

Ptychoparia ceus Walcott........ = *Liostracina krausei* Monke
Dorypygella typicalis Walcott...... = *Teiniston lansi* Monke
Damesella chione Walcott........ = *Stephanocare richthofeni* Monke

The following have not been identified in the material collected by Willis and Blackwelder:

Drepanura ketteleri Monke
Teinistion sodeni Monke

[1] Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, pp. 21-57: Beiträge zur Kenntniss des sibirischen Cambrium.

[2] Beiträge zur Geologie von Schantung: I. Obercambrische Trilobiten von Yen-tsy-yai. Jahrb. königl. preuss. geol. Landesanstalt und Bergakademie zu Berlin, Vol. 23, Pt. I, 1903, pp. 103-151.

I do not find that *Agnostus koerferi* Monke differs materially from *Agnostus chinensis* Dames, except in the unattached pygidium.

Teinistion lansi Monke is similar in many respects to *Shantungia spinifera* Walcott, but differs in the presence of an incurved frontal margin, and the absence of the long frontal spine.

The detailed sections and the succession of the contained faunas prove that the horizon of the fauna is in the upper part of the Middle Cambrian, and not Upper Cambrian, as determined by Monke.

In 1904 Dr. Th. Lorenz[1] described some problematical fossils? as Algæ under the new family Ascosomaceæ of the Siphoneæ. The genus *Ascosoma* was proposed to include one species, *Ascosoma phaneroporata,* and a second species was placed under a new genus as *Mitscherlichia chinensis.* Doctor Lorenz stated that he would soon publish a full description, with illustrations, of the new family, genera, and species, but on further study he decided that the fauna was neither algæ nor sponges.[2]

In 1905 some of the results of the Carnegie Institution of Washington Expedition to China were published by the writer, and a second paper appeared in 1906.[3] These two papers included descriptions and certain introductory notes on the Cambrian fossils collected by Messrs. Bailey Willis and Eliot Blackwelder that are included in this memoir. Subsequently lists of the species appeared in the report on the stratigraphic geology by Messrs. Willis and Blackwelder.[4]

Dr. Henry Woodward reviewed, in 1905, the work of Dr. H. Monke[5] and discussed some of the species occurring in a collection of fossils obtained from "West Shan-tung, and south of Tsing-tshou-fu, 36° 40′ N. lat., 118° 40′ E. long." A slab of the fossils from near Yen-tsy-yai is illustrated.

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[1] Centralblatt für Min., Geol. und Pal., 1904, No. 7, pp. 193-194: Ascosomaceæ, eine neue Familie der Siphoneen aus dem Cambrium von Schantung.

[2] Zeitschr. deutsch. geol. Gesellsch., Vol. 58, 1905: Beiträge zur Geologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der Provinz Schantung in China, I. Teil, pp. 12-13.

[3] Proc. U. S. National Museum, Vol. 29, 1905, pp. 1-106; Idem, Vol. 30, 1906, pp. 563-595.

[4] Research in China, Pt. I, pp. 19-43, 136-147, 272.

[5] On a collection of trilobites from the Upper Cambrian of Shantung, North China. Geological Magazine, London, new ser., Dec. V, Vol. 2, 1905, pp 211-215, 251-255, plate 13.

Late in 1906 a short memoir by Dr. Th. Lorenz appeared[1] in which he described a number of new genera and species of Cambrian fossils collected by him in the province of Shan-tung, and assigned stratigraphic horizons to them.

The fauna from Lai-wu was worked out of a single block found loose in the bed of a brook about 9 km. west of Lai-wu. Lorenz concludes that the fauna represents the time of the base of the Swedish Andrarum limestone, within the limits of the zone with *Paradoxides davidis* and *P. forchhammeri*.[2] The list of species given by him is as follows:

Olenoides (*Dorypyge*) *richthofeni* (Dames)
Agnostus fallax laiwuensis n. var.
Agnostus parvifrons Linnarsson
Anomocare commune n. sp.
Anomocare ovatum n. sp.
Alokistocare sp.
Amphoton steinmanni n. g. and sp.
Ptychoparia (*Solenopleura*) sp.
Hyolithes sp.
Raphistoma bröggeri Grönwall
Acrothele bohemica (Barrande)

From the descriptions and illustrations I have identified the above as follows:

Olenoides (*Dorypyge*) *richthofeni* (Dames)	=*Dorypyge richthofeni* Dames
Agnostus fallax laiwuensis Lorenz	=*Agnostus chinensis* Dames
Agnostus parvifrons Linnarsson	=*Agnostus* cf. *parvifrons* Linnarsson
Anomocare commune Lorenz	=*Anomocarella chinensis* Walcott
Anomocare ovatum Lorenz	=*Anomocare temenus* Walcott
Alokistocare sp. (not illustrated or described)	
Amphoton steinmanni Lorenz	=*Dolichometopus deois* Walcott
Raphistoma bröggeri Lorenz	=*Platyceras willisi* Walcott
Acrothele bohemica Barrande	=*Acrothele matthewi eryx* Walcott

The horizon of the *Dorypyge richthofeni* fauna in Shan-tung was definitely established by Messrs. Willis and Blackwelder as in the Middle Cambrian below the central part of the Kiu-lung group.[3] In Shan-si the fauna occurs in an oolitic limestone that, by its fauna, is related to the Ch'ang-hia oolite.[4]

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[1] Beiträge zur Geologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der Provinz Schantung in China, Vol. 58, 1906, II, Palæontologischer Teil. Von Herrn Th. Lorenz in Marburg a. d. Lahn. Hierzu Taf. 4-6 u. 55 text fig.

[2] Idem, p. 91.

[3] Blackwelder, Eliot. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, Part 1, 1907, Chap. 2, p. 40: Stratigraphy of Shan-tung.

[4] Idem, p. 145.

The fauna from Wang-tschuang occurs at three horizons. It is listed by Doctor Lorenz as follows:[1]

A lower layer with (*a*):
Anomocare speciosum Lorenz
Bathyuriscus asiaticus Lorenz
Agnostus fallax Linnarsson
Agnostus parvifrons latelimbatus Lorenz
Acrothele granulata Linnarsson

Eighty meters higher up, a layer with (*b*):
Teinistion (?) sp.
Drepanura (?) sp.

At 80 meters above, an upper layer has (*c*):
Shantungia buchruckeri Lorenz
Liostracus latus Lorenz

I have identified the above-listed fossils as follows:

(*a*) *Anomocare speciosum* Lorenz......=*Anomocarella speciosa* (Lorenz)
Bathyuriscus asiaticus Lorenz......=*Dolichometopus deois* Walcott
Agnostus fallax Linnarsson........=*A. chinensis* Dames
Agnostus parvifrons latelimbatus Lorenz ....=*A. latelimbatus* (Lorenz)
Acrothele granulata Linnarsson.....=*Acrothele matthewi eryx* Walcott
(*b*) *Teinistion* (?) sp..................=*Damesella* cf. *blackwelderi* Walcott
Drepanura (?) sp..................=*Damesella* cf. *blackwelderi* Walcott
(*c*) *Shantungia buchruckeri* Lorenz....=*Chuangia nitida* Walcott
Liostracus latus Lorenz............=*L. latus* Lorenz

By comparison with the sections of Messrs. Willis and Blackwelder fauna (*a*) is located in the lower portion of the Kiu-lung group at about the same horizon as the fauna from Lai-wu; fauna (*b*) represents the zone of *Damesella blackwelderi* Walcott, which occurs in the central part of the Kiu-lung group; and fauna (*c*), or the upper fauna, may be assigned to the upper limestone of the Kiu-lung group, where the Upper Cambrian fauna is well developed.[2]

At the locality of Tai-shan south of Tsi-nan Doctor Lorenz found fragments of a trilobite that he named *Lioparia blautoeides*, which I have identified as *Anomocarella baucis* Walcott, which occurs near the summit of the Upper Cambrian Ch'au-mi-tién limestone.

At the locality of Tsing-tshou-fu he reports the following:[3]

Lioparia latelimbata (Dames)
Shantungia crassa n. g. and sp.
A not closely definable brachiopod
Obolella nitida n. sp.[4]
Orthis sp.
Acrothele sp.

[1] Zeitschr. der deutsch. geol. Gesellsch., Vol. 58, 1906, Beiträge zur Geologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der provinz Schantung in China; II: Palæontologischer Teil, p. 93.

[2] Willis and Blackwelder, Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, 1907 (Apr.), Pt. 1, Descriptive topography and geology, pp. 23, 41.

[3] Lorenz, idem, p. 95.

[4] This is described as *Obolella gracilis* n. sp., on p. 88 of Lorenz, 1906.

My identification of the fauna is as follows:

Lioparia latelimbata (Dames) Lorenz..... = *Anomocare latelimbatum* Dames
Shantungia monkei Lorenz............... = *Pagodia monkei* (Lorenz)
Obolella gracilis Lorenz.................. = cf. *Obolus obscurus* Walcott
Orthis sp. and *Acrothele* sp.

I do not find any statement of Doctor Lorenz that the species enumerated by him were found in association. They do not appear to have come from the same stratigraphic horizon. *Pagodia monkei* (Lorenz) is essentially an Upper Cambrian type, while *Anomocare latelimbatum* Dames is from the Middle Cambrian.

I have not attempted to follow the classification of the trilobites given by Doctor Lorenz which is largely based on the division of the shell structure into non-porous (dense) and porous. The mineralization of most of the specimens is such that it is often impracticable to determine with any degree of satisfaction whether the shell is non-porous (dense) or porous.

By the courtesy of Dr. W. Deecke, of the Geological Institute of the University of Freiburg, I received eight pieces of the rock containing original specimens studied by Lorenz. These did not include the types of *Liostracus latus, Shantungia buchruckeri, Obolella gracilis,* or the specimens referred to *Drepanura* and *Teinistion*. I have had three of the specimens photographed (plate 7, fig. 1*a*; plate 20, fig. 8; plate 22, figs. 2, *2a, 2b*)[1] so that more direct comparison may be made. The original of *Shantungia monkei* Lorenz is too unsatisfactory to photograph.

The student of the Cambrian formations and faunas of China should consult the fine memoir of Dr. Eduard von Toll, 1899, on the Siberian Cambrian.[2] It has many suggestions that the future student of the Cambrian system in Asia should carefully consider. One of them is that a great and important work awaits the investigator of the Cambrian formations of Siberia. The field is a large one and what we now know of it indicates a rich reward to the individual who takes the time to thoroughly work out the formations and their contained faunas.

Mr. F. R. Cowper Reed, in discussing the pre-Carboniferous life provinces of Asia, points out that the Cambrian fauna of Spiti in

[1] The plate references in this paper are to be found in "The Cambrian Faunas of China," C. D. Walcott, 1913. Pub. No. 54, Carnegie Institution of Washington, Vol. 3.

[2] Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, pp. 1-57, pls. 1-8, and 9 text figs.: Beiträge zur Kenntniss des sibirischen Cambrium.

northern India has a stronger affinity with that of western North America than with any other Cambrian fauna.[1] The bearings of this are not enlarged upon further than to indicate a connection between the Himalayan region and North America during Middle Cambrian time.

The superb memoir of MM. J. Deprat and H. Mansuy, published as Volume 1, parts 1 and 2, of the Memoirs of the "Service géologique de l'Indo-Chine," 1912,[2] contains a great addition to our knowledge of the Cambrian rocks and faunas of Indo-China. Dr. Deprat[3] gives a very full description of the Cambrian formations as they occur at various localities with lists of the contained fossils. From this we learn that there is a series of coarse and fine sandstones at the base of the Cambrian some 500 meters (1,640 feet) thick that are overlain by shales, both calcareous and arenaceous, with interbedded quartzitic sandstones. Above the lower sandstones there are about 410 meters (1,345 feet) of beds containing remains of the trilobite genus *Redlichia*, that are referred to the Lower Cambrian, and from 200 to 300 meters (656 to 984 feet) of beds classed with the Middle Cambrian (Acadian). A great unconformity is indicated between these beds and the Ordovician strata by the absence of the Upper Cambrian and the lower Ordovician formations.

The faunas described by Dr. Mansuy from the Cambrian include:[4]

CAMBRIAN

ANNELIDS:

Planolites ?

BRACHIOPODS:

Obolus ? detritus Mansuy
Obolus damesi Walcott
Obolus cf. *chinensis* Walcott
Lingula yunnanensis Mansuy
Acrothele matthewi eryx Walcott
Acrothele orbicularis Mansuy

OSTRACODS:

Bradoria douvillei Mansuy
Aluta sp. ?
Nothozoe ?

TRILOBITES:

Redlichia chinensis Walcott
Redlichia nobilis Walcott
Redlichia walcotti Mansuy
Redlichia carinata Mansuy
Redlichia sp. ?
Palæolenus douvillei Mansuy
Palæolenus lantenoisi Mansuy
Palæolenus deprati Mansuy
Ptychoparia yunnanensis Mansuy

[1] Records Geol. Surv. India, Vol. 40, plate 1, 1910, p. 10.

[2] Mém. service géol. l'Indo-Chine, Vol. 1, 1912 (received May 8, 1913), fasc. 2, Étude géologique du Yun-Nan oriental, IIe partie, pp. 1-146, pls. 1-25: Paléontologie.

[3] Idem, Pt. 1, pp. 47-62.

[4] Idem, Pt. 2, pp. 1, 2.

SYNONYMIC REFERENCES

The following table mentions only those genera and species in which changes have been made since the publication of the original description and reference:

Former generic reference	*Present generic reference*
Agnostus koerferi Monke, 1903	*Agnostus douvilléi* Bergeron
Agraulos abaris Walcott, 1905	*Inouyia abaris* (Walcott)
Agraulos acalle Walcott, 1905	*Inouyia ? acalle* (Walcott)
Agraulos agenor Walcott, 1905	*Levisia agenor* (Walcott)
Agraulos armatus Walcott, 1906	*Inouyia ? armata* (Walcott)
Agraulos (?) capax Walcott, 1906	*Inouyia capax* (Walcott)
Agraulos divi Walcott, 1905	*Inouyia divi* (Walcott)
Agraulos (?) melie Walcott, 1906	*Inouyia melie* (Walcott)
Agraulos regularis Walcott, 1906	*Inouyia ? regularis* (Walcott)
Amphoton Lorenz, 1906	*Dolichometopus* Angelin
Amphoton steinmanni Lorenz, 1906	*Dolichometopus deois* Walcott
Anomocare bergioni Walcott, 1905	*Anomocarella bergioni* (Walcott)
Anomocare bianos Walcott, 1905	*Coosia ? bianos* (Walcott)
Anomocare bigsbyi Walcott, 1906	*Anomocarella bigsbyi* (Walcott)
Anomocare biston Walcott, 1905	*Anomocarella biston* (Walcott)
Anomocare ? butes Walcott, 1905	*Anomocarella butes* (Walcott)
Anomocare commune Lorenz, 1906	*Anomocarella chinensis* (Walcott)
Anomocare daunus Walcott, 1905	*Coosia ? daunus* (Walcott)
Anomocare decelus Walcott, 1905	*Coosia decelus* (Walcott)
Anomocare eriopia Walcott, 1906	*Ptychoparia (Emmrichella) eriopia* (Walcott)
Anomocare limbatum Angelin, 1854	*Coosia ? limbata* (Angelin)
Anomocare speciosum Lorenz, 1906	*Anomocarella speciosa* (Lorenz)
Anomocare tatian Walcott, 1905	*Anomocarella tatian* (Walcott)
Anomocare temenus Lorenz, 1906	*Anomocarella temenus* (Walcott)
Anomocare temenus Walcott, 1905	*Anomocarella temenus* (Walcott)
Anomocarella ? bura Walcott, 1905	*Lisania bura* (Walcott)
Anomocarella carme Walcott, 1905	*Coosia carme* (Walcott)
Anomocarella continua Walcott, 1906	*Anomocarella albion* (Walcott)
Arionellus agonius Walcott, 1905	*Lisania agonius* (Walcott)
Arionellus ajax Walcott, 1905	*Lisania ajax* (Walcott)
Arionellus alala Walcott, 1905	*Lisania alala* (Walcott)
Bathyuriscus asiaticus Lorenz, 1906	*Dolichometopus deois* Walcott
Bradoria bergeroni Walcott, 1905	*Aluta bergeroni* (Walcott)
Bradoria enyo Walcott, 1905	*Aluta enyo* (Walcott)
Bradoria eris Walcott, 1905	*Aluta eris* (Walcott)
Bradoria fragilis Walcott, 1905	*Aluta fragilis* (Walcott)
Bradoria sterope Walcott, 1905	*Aluta sterope* (Walcott)
Bradoria woodi Walcott, 1905	*Aluta woodi* (Walcott)
Calymmene ? sinensis Bergeron, 1899	*Blackwelderia sinensis* (Bergeron)
Conocephalites subquadratus Dames, 1883	*Anomocare subquadratum* (Dames)
Conocephalites typus Dames, 1883	*Ptychoparia typus* (Dames)

Former generic reference	*Present generic reference*
Craniella ?? sp. Walcott, 1905	*Discinopsis sulcatus* (Walcott)
Damesella Walcott, 1905	*Stephanocare* Monke
Damesella chione Walcott, 1905	*Stephanocare richthofeni* Monke
Damesella sinensis Walcott, 1905	*Stephanocare ? sinensis* (Bergeron)
Dicellocephalus ? sinensis Bergeron, 1899	*Stephanocare ? sinensis* (Bergeron)
Dikelocephalus ? baubo Walcott, 1905	*Ptychaspis baubo* (Walcott)
Dikelocephalus ? brizo Walcott, 1905	*Ptychaspis brizo* (Walcott)
Dorypygella Walcott, 1905	*Teinistion* Monke
Dorypygella alastor Walcott, 1905	*Blackwelderia alastor* (Walcott)
Dorypygella alcon Walcott, 1905	*Teinistion alcon* (Walcott)
Dorypygella typicalis Walcott, 1905	*Teinistion typicalis* (Walcott)
Hoeferia Redlich, 1901	*Redlichia* Cossman, 1902
Illænurus canens Walcott, 1913	*Tsinania canens* (Walcott) [1]
Illænurus ceres Walcott, 1913	*Tsinania ceres* (Walcott)
Illænurus dictys Walcott, 1913	*Tsinania dictys* (Walcott)
Illænurus sp. Walcott, 1913	*Tsinania* sp. (Walcott)
Liostracus megalurus Dames, 1883	*Anomocare megalurus* (Dames)
Menocephalus adrastia Walcott, 1905	*Levisia adrastia* (Walcott)
Menocephalus belenus Walcott, 1905	*Lisania belenus* (Walcott)
Obolus (Lingulepis) eros Walcott, 1905	*Lingulella (Lingulepis) eros* (Walcott)
Obolus (Lingulepis ?) sp. undt. Walcott 1906	*Lingulella (Lingulepis ?)* sp. undt. (Walcott)
Olenoides ? cilix Walcott, 1905	*Blackwelderia cilix* (Walcott)
Olenoides leblanci Bergeron, 1899	*Blackwelderia sinensis* (Bergeron)
Orthis linnarssoni Kayser, 1883	*Eoorthis linnarssoni* (Kayser)
Orthis (Plectorthis) agreste Walcott, 1906	*Eoorthis agreste* (Walcott)
Orthis (Plectorthis) doris Walcott, 1905	*Eoorthis doris* (Walcott)
Orthis (Plectorthis) kayseri Walcott, 1905	*Eoorthis kayseri* (Walcott)
Orthis (Plectorthis) kichouensis Walcott, 1906	*Eoorthis kichouensis* (Walcott)
Orthis (Plectorthis) linnarssoni Walcott, 1905	*Eoorthis linnarssoni* (Kayser)
Orthis (Plectorthis) pagoda Walcott, 1905	*Eoorthis pagoda* (Walcott)
Orthis (Plectorthis) sp. undt. Walcott, 1906	*Eoorthis* sp. undt. (Walcott)
Platyceras chronus Walcott, 1905	*Pelagiella chronus* (Walcott)
Platyceras clytia Walcott, 1905	*Pelagiella clytia* (Walcott)
Platyceras pagoda Walcott, 1905	*Pegaliella pagoda* (Walcott)
Platyceras willisi Walcott, 1906	*Pelagiella willisi* (Walcott)
Ptychoparia ? batia Walcott, 1905	*Chuangia batia* (Walcott)
Ptychoparia ? bromus Walcott, 1905	*Ptychoparia (Emmrichella) bromus* (Walcott)
Ptychoparia ceus Walcott, 1905	*Liostracina krausei* Monke
Ptychoparia comus Walcott, 1906	*Anomocarella comus* (Walcott)

[1] For description of new genus *Tsinania*, see page 43, this paper.

Former generic reference	*Present generic reference*
Ptychoparia constricta Walcott, 1905	*Ptychoparia* (*Emmrichella*) *constricta* (Walcott)
Ptychoparia dryope Walcott, 1905	*Conokephalina ? dryope* (Walcott)
Ptychoparia granulosa Walcott, 1905	*Ptychoparia granosa* Walcott
Ptychoparia inflata Walcott, 1906	*Inouyia ? inflata* (Walcott)
Ptychoparia (?) *maia* Walcott, 1906	*Conokephalina maia* (Walcott)
Ptychoparia mantoensis Walcott, 1905	*Ptychoparia* (*Emmrichella*) *mantoensis* (Walcott)
Ptychoparia nereis Walcott, 1906	*Anomocare ? nereis* (Walcott)
Ptychoparia tellus Walcott, 1905	*Lonchocephalus tellus* (Walcott)
Ptychoparia tenes Walcott, 1905	*Anomocarella tenes* (Walcott)
Ptychoparia theano Walcott, 1905	*Ptychoparia* (*Emmrichella*) *theano* (Walcott)
Ptychoparia titiana Walcott, 1905	*Inouyia titiana* (Walcott)
Ptychoparia undata Walcott, 1906	*Anomocarella undata* (Walcott)
Ptychoparia vesta Walcott, 1906	*Conokephalina vesta* (Walcott)
Ptychoparia sp. undt. Walcott, 1906	*Conokephalina* sp. undt. (Walcott)
Ptychoparia (*Liostracus*) *intermedia* Walcott, 1906	*Solenopleura intermedia* (Walcott)
Ptychoparia (*Liostracus*) *megalurus* Walcott, 1905	*Anomocare megalurus* (Dames)
Ptychoparia (*Liostracus*) *subrugosa* Walcott, 1906	*Anomocarella subrugosa* (Walcott)
Ptychoparia (*Liostracus*) *thraso* Walcott, 1905	*Anomocarella thraso* (Walcott)
Ptychoparia (*Liostracus*) *toxeus* Walcott, 1905	*Anomocarella toxeus* (Walcott)
Ptychoparia (*Liostracus*) *trogus* Walcott, 1905	*Anomocarella trogus* (Walcott)
Ptychoparia (*Liostracus*) *tutia* Walcott, 1905	*Anomocarella tutia* (Walcott)
Ptychoparia (*Proampyx*) *burea* Walcott, 1905	*Proampyx burea* (Walcott)
Shantungia Lorenz, 1906	*Chuangia* Walcott
Shantungia Walcott, 1905	*Shangtungia* Walcott
Shantungia buchruckeri Lorenz 1906	*Chuangia nitidia* Walcott
Solenopleura abderus Walcott, 1905	*Menocephalus abderus* (Walcott)
Solenopleura acantha Walcott, 1905	*Menocephalus acanthus* (Walcott)
Solenopleura acidalia Walcott, 1905	*Menocephalus acidalia* (Walcott)
Solenopleura belus Walcott, 1905	*Conokephalina belus* (Walcott)
Stenotheca clurius Walcott, 1905	*Helcionella clurius* (Walcott)
Stenotheca rugosa chinensis Walcott, 1905	*Helcionella rugosa chinensis* (Walcott)
Stenotheca rugosa orientalis Walcott, 1905	*Helcionella rugosa orientalis* (Walcott)
Stenotheca simplex Walcott, 1906	*Helcionella ?? simplex* (Walcott)

Former generic reference	*Present generic reference*
Stephanocare sinensis Monke, 1903.........	*Blackwelderia sinensis* (Bergeron)
Straparollina circe Walcott, 1905...........	*Matherella circe* (Walcott)
Syntrophia orientalis Walcott, 1905.........	*Huenella orientalis* (Walcott)

LOCALITIES (WITH LISTS OF GENERA AND SPECIES AT EACH)

For convenience of reference and to avoid repetition, the following localities, with the genera and species found in each, are inserted. The lists published by Willis and Blackwelder[1] are composite lists made up by writing the lists of fossils from several localities in one list in order to give the fauna that in their judgment occurs at some one stratigraphic horizon of the Cambrian. For the purposes of the future student who may wish to study the geographic distribution of the various subfaunas and to work out the limits of the formations containing them, the local lists are essential and give all known data concerning localities from which fossils described in this paper have been obtained. When not otherwise stated, the collections were made by Dr. Eliot Blackwelder.

Chinese Localities

C 1. Just below C 2, same section; just above C 4, same section; about 75 feet below C 62, which occurs at a locality 3 miles east; about same horizon as C 10, different section; about 150 feet below C 12, same section.

Middle Cambrian: Lower shale member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 40 (part of the third list of fossils), and fig. 10 (bed 4), p. 38], 2 miles (3.2 km.) south of Yen-chuang, Sin-ta'i district, Shan-tung. (At the second "x" from left side of section given on page 38 of Blackwelder, 1907, Research in China.)

Protospongia chloris
Obolus minimus
Obolus (*Westonia*) *blackwelderi*
Acrotreta pacifica
Acrotreta shantungensis ?
Pelagiella chronus
Hyolithes cybele
Agnostus chinensis
Dorypyge richthofeni
Inouyia divi
Lisania agonius
Anomocarella albion
Anomocarella chinensis
Dolichometopus alceste
Dolichometopus deois
Dolichometopus derceto

[1] Willis and Blackwelder, Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, 1907, Pt. 1, pp. 1-353, figs. 1-65: Descriptive topography and geology.

C 2 Just above C 1, same section; above C 4, same section; about same horizon as C 10, different section.

Middle Cambrian: Lower shale member of the Kiu-lung [Blackwelder, 1907, pp. 37 and 40 (part of the third list of fossils), and fig. 10 (beds 4 and 5), p. 38], 2 miles (3.2 km.) south of Yen-chuang, Sin-t'ai district, Shan-tung. C 2 contains specimens from the central portion of the lower shale member—from the second "x" from the left side of the figure on page 38 to but not including the fourth "x" from the left.

Protospongia chloris
Obolus (Westonia) blackwelderi
Acrotreta pacifica
Hyolithes cybele
Orthotheca cyrene dryas
Agnostus chinensis
Dorypyge bispinosa
Lonchocephalus tellus
Lisania agonius
Anomocare latelimbatum
Anomocarella albion
Anomocarella biston
Anomocarella chinensis
Coosia ? daunus
Dolichometopus deois
Dolichametopus derceto

C 3. About 100 feet above the horizon of C 60, different section; about 175 feet below the horizon of C 8, different sections.

Lower Cambrian: Lower part of the Man-t'o shale formation [Blackwelder 1907, p. 28 (list of fossils at bottom of page), and fig. 8*a* (bed 20), p. 28], on the southeast slope of Hu-lu-shan, 2.5 miles (4 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

Billingsella richthofeni
Helcionella rugosa chinensis
Hyolithes delia
Redlichia nobilis
Ptychoparia (Emmrichella) constricta

C 4. Just below C 1, same section; same horizon as C 57, different section.

Middle Cambrian: In limestone nodules at the base of the lower shale member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 40 (second list of fossils), and fig. 10 (bed 4), p. 38], 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. In the section on page 38 of Blackwelder, 1907, this horizon is at the base of bed 4 about halfway between the first and second "x's" from the left side.

Protospongia chloris
Acrothele matthewi eryx
Acrotreta pacifica
Pelagiella chronus
Hyolithes cybele
Hyolithes ? (operculum)
Orthotheca delphus
Agnostus chinensis
Lisania alala
Anomocarella albion
Anomocarella chinensis
Dolichometopus alceste
Dolichometopus deois

C 5. About 25 feet above C 8, same section; about 40 feet below C 63, same section.

Middle Cambrian: Lower limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 39 (first list of fossils), and fig. 8*a* (bed 30), p. 29], 3.2 miles (5.1 km.) southwest of Yen-chuang,

Sin-t'ai district, Shan-tung. In the section on page 29 of Blackwelder, 1907, this horizon is at the bed marked "30." On the figure this is placed as occurring below the line dividing the Man-t'o from the Kiu-lung, but on the basis of the fauna contained in it the limestone is referred to the base of the Kiu-lung. The text [p. 39] places the boundary between the Kiu-lung and the Man-t'o, 15 feet below C 5.

Globigerina ? mantoensis
Micromitra (Iphidella) pannula ophirensis
Acrotreta pacifica
Inouyia divi
Anomocare sp.
Anomocarella butes
Dolichometopus ? sp.

C 6. About 120 feet above C 12, same section; about 20 feet below C 61, same section.

Middle Cambrian: Thin platy limestone in the upper shale member of the Kiu-lung group just below the Ch'au-mi-tién limestone [Blackwelder, 1907, pp. 37 and 41 (second list of fossils), and fig. 10 (bed 12), p. 38], 2.5 miles (4 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

Obolus (Westonia) blackwelderi
Dicellomus parvus
Acrothele ? minuta
Agnostus douvilléi
Redlichia sp. undt.
Stephanocare ? monkei
Stephanocare richthofeni
Stephanocare ? sinensis
Stephanocare ? sp. undt.
Blackwelderia sinensis
Drepanura ketteleri
Drepanura premesnili
Ptychoparia (Emmrichella) bromus
Liostracina krausei
Shantungia spinifera

C 7. Just above C 9, same section; about same horizon as C 52, different section; about 200 feet below C 10, same section.

Middle Cambrian: Lower limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 39 (last list of fossils), and fig. 8*a* *bed* 33), p. 29], 2.2 miles (3.5 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. In the section on page 29 of Blackwelder, 1907, this horizon is not starred, but occurs at about the middle of the lower of the two bands of oolitic limestone numbered "33."

Obolus damesi
Lingulella (Lingulepis) eros
Inouyia abaris
Inouyia titiana
Agraulos dolon
Anomocare subquadratum
Anomocarella subrugosa
Anomocarella thraso

C 8. About 25 feet below C 5, same section; about 275 feet above C 60, same section; about 175 feet above the horizon of C 3, different section.

Middle Cambrian: Brown sandstone and limestone nodules in brown micaceous shales near the top of the Man-t'o formation [Blackwelder, 1907, fig. 8*a* (bed 27), p. 29], 3.4 miles (5.4 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. This horizon is starred opposite bed "27" on the section on page 29 of Blackwelder, 1907. This is below the line between the Kiu-lung and the Man-t'o,

both as represented on page 29 and as given in the text at the top of page 39.

Two species, *Ptychoparia impar.* var. and *Anomocare* sp. undt.

C 9. Just below C 7, same section; about 25 feet above C 63, same section; about same horizon as C 52, different section.

Middle Cambrian: Lower limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 39 (third list of fossils), and fig. 8*a* (bed 33), p. 29], 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. In this section on page 29 of Blackwelder, 1907, this horizon is not starred, but occurs at the base of the lower of the two bands of oolitic limestone numbered "33."

Micromitra (Paterina) labradorica orientalis
Inouyia abaris
Anomocare minus
Coosia decelus

C 10. About 200 feet above C 7, same section; about same horizon as C 1, C 2, and C 4, different section.

Middle Cambrian: Lower shale member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 40 (part of the third list of fossils), and fig. 8*a* (bed 35), p. 29], about 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

Obolus damesi
Menocephalus sp. undt.
Anomocarella temenus

C 11. About same horizon as C 61, different section; above C 57, same section; about same horizon as C 33*a*, different section.

Upper Cambrian: Crystalline limestone 60 feet (18 m.) above the base of the uppermost limestone member [Blackwelder, 1907, pp. 37 and 41 (last list of fossils)] 2.1 miles (3.4 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

Two species, *Chuangia batia* and *Chuangia nitida.*

C 12. About 120 feet below C 6, same section; about 75 feet above C 62, same section but at a locality 3 miles east; C 13 includes the horizon represented by C 12; about 150 feet above C 1, same section.

Middle Cambrian: Gray limestone near the top of the middle limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 41 (part of the first list of fossils), and fig. 10 (bed 7), p. 38], 3.25 miles (5.2 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. This horizon is starred at the top of bed "7" in the section on page 28.

Acrotreta pacifica
Teinistion alcon
Teinistion typicalis
Blackwelderia alastor
Damesella blackwelderi
Pterocephalus asiaticus
Inouyia acalle
Lisania ajax
Anomocarella tutia

C 13. The horizon of C 13 includes that of C 12; about 120 feet below C 6, same section; about 75 feet above C 62; which is in the same section but at a locality 3 miles east; about 150 feet above C 1, same section.

Middle Cambrian: Yellow slabby limestone in the middle limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 41, part of the first list of fossils), on the west slope of hill in angle between two faults, just east of the granite mass of the Lién-hua-shan, 6 miles (9.6 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. Collected at some distance from C 12 and includes more. Its horizon is that of bed 7 of fig. 10, page 38.

Two species, *Damesella bella granulata* and *Damesella blackwelderi*.

C 14. From the horizons of C 12 and C 13.

Middle Cambrian: In talus from the middle limestone member of the Kiu-lung group [Blackwelder, 1907, p. 37], 2.8 miles (4.5 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. Field label says section 6 K, stratum 11, which is about 200 feet above C 61. Note by C. D. Walcott says it is from stratum 4, the horizon of C 12 and C 13.

One species, *Damesella blackwelderi*.

C 15. About same horizon as C 16 and C 27.

Lower Cambrian: Slaty black limestone in the lower part of the Man-t'o shale [Blackwelder, 1907, p. 26, third paragraph; and fig. 6 (bed 7), p. 25], at Ch'ang-hia, Shan-tung.

One species, *Redlichia chinensis*.

C 16. About same horizon as C 15 and C 27.

Lower Cambrian: Slaty black limestone in the lower part of the Man-t'o shale [Blackwelder, 1907, p. 26, third paragraph; and fig. 6 (bed 7), p. 25], 2 miles (3.2 km.) south of Ch'ang-hia, Shan-tung.

Two species, *Redlichia chinensis* and *Redlichia* sp. undt.

C 17. About 180 feet below C 23, same section; about 35 feet above C 20, adjacent sections; about 160 feet below C.28, adjacent sections.

Lower Cambrian: Ferruginous limestone nodules in the brown sandy shales at the top of the Man-t'o shale [Blackwelder, 1907, p. 27 (list of fossils at top of page) and fig. 6 (bed 15), p. 25], at Ch'ang-hia, Shan-tung.

Obolella asiatica
Ptychoparia aclis
Ptychoparia granosa
Ptychoparia impar

C 18. Below horizon of C 19, C 22, C 24, and C 26, same section; above C 21, same section.

Middle Cambrian: Dark gray oolitic limestone about 400 feet (120 m.) above the base of the Ch'ang-hia limestone [Blackwelder, 1907, p. 33, third list of fossils], in cliffs 1 mile (1.6 km.) east of Ch'ang-hia, Shan-tung.

Scenella clotho
Pelagiella chronus
Helcionella rugosa orientalis
Crepicephalus damia
Crepicephalus magnus
Menocephalus acerius

C 19. About the same horizon as C 22, C 24, and C 26, same section; about same horizon as C 25, different section.

Middle Cambrian: Uppermost layers of the Ch'ang-hia limestone [Blackwelder, 1907, p. 33, part of the last list of fossils], at Ch'ang-hia, Shan-tung.

Dorypyge richthofeni
Damesella brevicaudata
Lisania belenus
Menocephalus abderus
Anomocare daulis
Anomocarella tutia
Dolichometopus deois

C 20. About 15 feet above C 31, same section; about 35 feet below C 17, different section.

Lower Cambrian: Central part of the Man-t'o shale formation [Blackwelder, 1907, p. 26 (last list of fossils) and fig. 6 (bed 14), p. 25], on the west side of an isolated butte 1 mile (1.6 km.) south of Ch'ang-hia, Shan-tung.

Billingsella richthofeni
Ptychoparia aclis
Ptychoparia (Emmrichella) mantoensis

C 21. About 100 feet above C 30, different sections; about 100 feet below C 18, same section.

Middle Cambrian: Ocher-mottled phase of purple-gray limestone in the middle of the oolitic Ch'ang-hia formation [Blackwelder, 1907, p. 33, second list of fossils], at Ch'ang-hia, Shan-tung.

Helcionella rugosa orientalis
Crepicehpalus damia
Solenopleura sp. undt.

C 22. About same horizon as C 19, C 24, and C 26, same section; above C 18, same section.

Middle Cambrian: Ch'ang-hia limestone in upper oolitic portion [Blackwelder, 1907, pp. 22 and 33 (part of the last list of fossils)], at Ch'ang-hia, Shan-tung.

Acrotreta lisani
Hyolithes cybele
Lisania alala
Lisania bura
Menocephalus acantha
Menocephalus admeta
Anomocarella temenus

C 23. About 180 feet above C 17, same section; about 25 feet above C 28, different section.

Middle Cambrian: Upper part of thin-bedded gray oolitic limestone at the base of the Ch'ang-hia formation [Blackwelder, 1907, p. 32 (second list of fossils), and fig. 6 (bed 20), p. 25], 50 feet (15 m.) below the base of the cliffs 1 mile (1.6 km.) east-southeast of Ch'ang-hia, Shan-tung. This horizon is the fourth bed above the black line in the figure on page 25, the one opposite bed "20."

Acrothele rara
Orthotheca daulis
Ptychoparia (Emmrichella) eriopia
Ptychoparia (Emmrichella) theano
Agraulos abrota
Anomocarella tatian

C 24. About same horizon as C 19, C 22, and C 26, same section; above C 18, same section; about same horizon as C 25, different section.

Middle Cambrian: Near top of black oolite group in the uppermost layers of the Ch'ang-hia formation [Blackwelder, 1907, p. 33, part of the last list of fossils], 2 miles (3.2 km.) each of Ch'ang-hia, Shan-tung.

Acrotreta cf. *pacifica*
Dorypyge richthofeni
Agnostus sp. undt. (pygidium)
Inouyia divi
Dolichometopus dirce

C 25. About same horizon as C 19, C 22, C 24, and C 26, different section; above C 35, same section.

Middle Cambrian: Limestone about 50 feet (15 m.) below the Ku-shan shale in the uppermost beds of the Ch'ang-hia formation [Blackwelder, 1907, p. 33, part of the last list of fossils], at Ch'ang-hia, Shan-tung.

Crepicephalus cf. *magnus*
Solenopleura agno
Levisia agenor
Anomocare sp.
Anomocarella trogus

C 26. About same horizon as C 19, C 22, and C 24, same section; about same horizon as C 25, different section; above C 18, same section.

Middle Cambrian: Near the top of the black oolite group in the uppermost layers of the Ch'ang-hia limestone [Blackwelder, 1907, p. 33, part of the last list of fossils], 2 miles (3.2 km.) north-northeast of Ch'ang-hia, Shan-tung.

Eoorthis sp. undt.
Crepicephalus damia
Anomocare ? daulis

C 27. About same horizon as C 15 and C 16.

Lower Cambrian: Buff and drab shales in the lower part of the Man-t'o shale [Blackwelder, 1907, p. 26, third paragraph; and fig. 6 (bed 7), p. 25], on crest of ridge at Ch'ang-hia, Shan-tung.

Two species: *Redlichia chinensis* and *Redlichia* sp.

C 28. About 200 feet above C 20, same section; about 160 feet above C 17, adjacent section; about 25 feet below C 23, different section.

Middle Cambrian: Thin-bedded oolitic limestone at the base of the Ch'ang-hia limestone [Blackwelder, 1907, p. 32 (first list of fossils), and fig. 6 (bed 20), p. 25], just above the shales in the face of the cliff 1 mile (1.6 km.) east-southeast of Ch'ang-hia, Shan-tung. This horizon is the first layer in bed "20" (see figure on p. 25) above the black line.

Eoorthis agreste
Inouyia thisbe
Anomocarella tenes
Anomocarella toxeus
Bathyuriscus ? sp.

C 29. Below C 30, same section; about same horizon as C 48, different section.

Middle Cambrian: Near the top of the cliffy limestone in the Ch'ang-hia limestone [Blackwelder, 1907, p. 32, part of the last list of fossils], 1 mile (1.6 km.) west of Ch'ang-hia, Shan-tung.

Two species: *Dorypyge richthofeni* and *Agraulos dryas*.

C 30. About 100 feet below C 21, different section; above C 29, same section; below C 35, same section; about same horizon as C 51, different section.

Middle Cambrian: Layer in black oolite of Ch'ang-hia limestone [Blackwelder, 1907, p. 33, part of the first list of fossils], 25 feet 7.5 m.) above the second cliff at an elevation of 1,700 feet (568.9 m.) on top of the long north and south ridge at Ch'ang-hia, Shan-tung.

Dorypyge richthofeni
Lisania alala
Lisania sp. undt.
Anomocare sp.
Menocephalus acidalia
Menocephalus agave
Levisia adrastia

C 31. About 15 feet below C 20, same section.

Lower Cambrian: Gray crystalline limestone in the central portion of the Man-t'o shale [Blackwelder, 1907, p. 26 (first list of fossils), and fig. 6 (bed 12), p. 25], at Ch'ang-hia, Shan-tung.

Ptychoparia aclis
Ptychoparia ligea
Ptychoparia (*Emmrichella*) *mantoensis*

C 32. See also C 32′, other drift blocks at the same locality.

Middle Cambrian: A fine-grained bluish-black limestone bowlder believed to have come from the lower part of the Ki-sin-ling limestone [Blackwelder, 1907, p. 272], collected in river drift 1 mile (1.6 km.) south of Chön-p'ing-hién, on the Nan-kiang River, southern Shen-si.

Obolus shansiensis
Dicellomus parvus
Acrotreta shantungensis
Orthotheca doris
Microdiscus orientalis
Aluta bergeroni
Aluta enyo
Aluta eris
Aluta fragilis
Aluta sterope
Aluta woodi

C 32′. See C 32, another drift block at the same locality.

Lower Cambrian: A limestone bowlder collected in river drift 1 mile (1.6 km.) south of Chön-p'ing-hién, on the Nan-kiang River, southern Shen-si.

Two species: *Obolella asiatica* and *Hyolithes* sp. undt.

C 33. *Upper Cambrian*: About 100 feet (30 m.) above the base of the Ch'au-mi-tién limestone, 9 miles (14.4 km.) north of Sin-t'ai-hién, Shan-tung.

One species, *Ptychaspis* sp. (free cheeks and fragments).

C 33*a*. About same horizon as C 11, different section.

Upper Cambrian: Talus near the base of the cliff of Ch'au-mi-tién limestone [Blackwelder, 1907, p. 41, part of the last list of fossils], 9 miles (14.4 km.) north of Sin-t'ai-hién, Shan-tung.

Two species, *Chuangia batia* and *Anomocarella bergioni*.

C 34. About same horizon as C 38, C 41, and C 49, different sections.
Upper Cambrian: Purplish-gray limestone about 100 feet (30 m.) above the base of the Ch'au-mi-tién formation [Blackwelder, 1907, p. 36, part of the first list of fossils] in road at northeastern corner of small village near Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Pagodia macedo
Agnostus sp. undt.
Ptychaspis ceto
Tsinania canens

C 35. Below C 25, same section.
Middle Cambrian: Upper part of the Ch'ang-hia limestone [Blackwelder, 1907, p. 33, fifth paragraph], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.
One species, *Menocephalus acis.*

C 36. About same horizon as C 45, different section; about same horizon as C 50, same section; above C 68, same section; about same horizon as C 47, same section.
Upper Cambrian: Upper part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36 (part of the third list of fossils), and fig. 9 (bed 2), p. 35], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.
Two species, *Billingsella pumpellyi* and *Anomocarella baucis.*

C 37. About same horizon as C 72, same section; about 50 feet above C 71, same section; about 200 feet below C 73, same section; about 225 feet below C 74, same section.
Middle Cambrian: Upper part of the Ki-chóu limestone,[1] in dense black limestone nodules in green-gray shales 10 feet (3 m.) below the base of the cliff limestone, 8 miles (12.8 km.) south of Ting-hiang-hién, Shan-si.

Obolus shansiensis
Acrotreta shantungensis
Anomocare megalurus

C 38. About same horizon as C 34, C 41, and C 49, different sections; below C 43, same section.
Upper Cambrian: Crystalline limestone near the base of the Ch-au-mi-tién limestone [Blackwelder, 1907, p. 36, part of the first list of fossils], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Coosia carme
Ptychaspis brizo
Ptychaspis ceto
Hysterolenus sp.
Tsinania canens
Tsinania ceres

C 39 = *Ordovician.*

C 40. About same horizon as C 12, C 13, and C 14, same section.
Middle Cambrian: Limestone nodules in green shales in the middle limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 41 (part of the first list of fossils)], in a gully in bank of river 2 miles (3.2 km.) south of Yen-chuang, Sin-t'ai district, Shan-tung.
Two species: *Damesella blackwelderi* and *Lisania ajax.*

[1] The fossils from this locality are not listed, but the presence of Cambrian strata at the locality is mentioned by Willis and Blackwelder [1907, p. 146]).

C 41. Same horizon as C 49, C 54, and C 56, same section; about same horizon as C 34 and C 38, different section.

Upper Cambrian: Lower part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36, part of the first list of fossils], 2.7 miles (4.3 km.) southwest of Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Lisania sp. undt.
Pagodia dolon
Ptychaspis cadmus
Ptychaspis calchas
Tsinania canens

C 42. *Upper Cambrian*: In the central part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36, second list of fossils], 1.8 miles (2.9 km.) west-southwest from the temple of Tsing-lung-shan, 7.5 miles (12 km.) east of Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Ptychaspis calyce
Ptychaspis campe
Tsinania canens

C 43. Above C 38, same section.

Upper Cambrian: Near the top of crystalline, mostly purple-gray limestone in the Ch'au-mi-tién limestone, at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

No identifiable species.

C 44. *Upper Cambrian*: In talus 200 feet (60 m.) above the top of the section containing C 46, C 48, and C 51, at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

One species, *Chuangia batia*.

C 45. Same horizon as C 36 and C 68, different section; about 900 feet (270 m.) above C 25, same section; supposed to be from same horizon as C 50 and C 67.

Upper Cambrian: Limestone about 40 feet (12 m.) below the top of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36 (part of third list of fossils)], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Ptychaspis acamus
Ptychaspis ceto
Tsinania sp. undt.

C 46. Above C 51, same section; about same horizon as C 75, different section.

Middle Cambrian: Light gray crystalline limestone in the Ch'ang-hai limestone [Blackwelder, 1907, p. 33, fourth list of fossils], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Helcionella ? clurius
Lisania alala
Anomocare sp. (free cheek and pygidium)
Damesella sp. (free cheek)
Damesella ? sp. (free cheek)

C 47. About same horizon as C 36, same section.

Upper Cambrian: Upper part of the Ch'au-mi-tién limestone [Blackwelder, 1907, fig. 9 (top of bed 1), p. 35], at the top of a high col at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Pelagiella clytia
Orthotheca cyrene
Ptychaspis sp.

C 48. Below C 51, same section; about same horizon as C 29, different section.
Middle Cambrian: Near the top of the cliffy oolitic limestone in the Ch'ang-hia limestone [Blackwelder, 1907, p. 32, part of the last list of fossils], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.
Two species, *Ptychoparia* sp. undt. and *Crepicephalus magnus*.

C 49. Same horizon as C 41, C 54, and C 56, same section; about same horizon as C 34 and C 38, different sections.
Upper Cambrian: Purplish-brown limestone in the lower part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36, part of the first list of fossils], in roadway 2.5 miles (4 km.) west-southwest of Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.
One species, *Menocephalus ? depressus*.

C 50. About same horizon as C 36, C 47, and C 68, same section; supposed to be from horizon of C 45 and C 67.
Upper Cambrian: Upper part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36 (part of the third list of fossils)], on a low spur at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.
One species, *Ptychaspis* sp.

C 51. Below C 46, same section; above C 48, same section; about same horizon as C 30, different section.
Middle Cambrian: Lower part of gray crystalline limestone in the upper portion of the oolitic part of the Ch'ang-hia limestone [Blackwelder, 1907, p. 33, part of the first list of fossils], at Ch'au-mi-tién, Ch'ang-hia district, Shan-tung.

Shumardia sp.
Lisania alala
Solenopleura agno
Solenopleura intermedia

C 52. *Middle Cambrian*: In the lower part of the lower limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 39 (second list of fossils), and fig. 7 (bed 22), p. 27], near base of cliffs in mountain 1,000 feet (305 m.) high, 3 miles (4.8 km.) north-northeast of Sin-t'ai-hién, Shan-tung.

Ptychoparia tolus
Agraulos dirce
Anomocare latelimbatum
Anomocarella butes

C 53 = *Ordovician*.

C 54. Same horizon as C 41, C 49, and C 56; about same horizon as C 34 and C 38, different sections.
Upper Cambrian: Lower part of Ch'au-mi-tién limestone [Blackwelder, 1907, p. 42 (part of the last list of fossils)], near top of limestone knoll two-thirds of a mile (1.1 km.) west of Tsi-nan, Shan-tung.

Obolus matinalis ?
Eoorthis pagoda
Syntrophia orthia
Pterocephalus busiris
Ptychaspis ceto
Ptychaspis sp. undt. (free cheek)
Tsinania canens
Tsinania sp. undt. (pygidium)

C 55. (See C 6.)

Middle Cambrian: Thin platy limestone in the upper shale member of the Kiu-lung group just below the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 43], in isolated hills at an elevation of 380 feet (114 m.) above the Wön-ho, 12 miles (19 km.) south, 80° east of Tsi-nan, Shan-tung.

Straparollina sp. undt.
Agnostus douvilléi
Stephanocare richthofeni
Blackwelderia cilix
Drepanura ketteleri
Drepanura premesnili

C 56. Same horizons as C 41, C 49, and C 54.

Upper Cambrian: Lower part of Ch'au-mi-tién limestone, 25 feet (7.5 m.) below the top of Pagoda Hill [Blackwelder, 1907, p. 42 (part of the last list of fossils)], 1 mile (1.6 km.) west of Tsi-nan, Shan-tung.

Obolus (*Westonia*) sp. undt.
Discinopsis sulcatus
Eoorthis pagoda
Syntrophia orthia
Scenella sp. undt.
Matherella circe
Pelagiella pagoda
Orthotheca sp. undt.
Cyrtoceras cambria
Conokephalina belus
Conokephalina dryope
Pagodia bia
Pagodia lotos
Menocephalus ? depressus
Ptychaspis ceto
Hysterolenus ? (pygidium)
Tsinania dictys

C 57. Same horizon as C 4, different section; below C 11, same section; above C 58, same section.

Middle Cambrian: In limestone nodules in the lower shale member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 40 (first list of fossils)], 3 miles (4.8 km.) south of Kao-kia-p'u, and 4 miles (6.4 km.) north of Sin-t'ai-hién, Sin-t'ai district, Shan-tung.

Acrothele rara
Orthotheca delphus
Agnostus chinensis
Agnostus kushanensis
Dorypyge richthofeni
Anomocare alcinoe
Anomocarella albion
Anomocarella chinensis
Dolichometopus deois

C 58. Below C 57, same section.

Middle Cambrian: Green shale near the middle of the Ch'ang-hia limestone, at top of hill 2 miles (3.2 km.) south-southeast of Kao-kia-p'u, Shan-tung.

Two species, *Redlichia finalis* and *Ptychoparia ?* sp. (pygidium).

C 59 = *Ordovician* and *Carboniferous*.

C 60. About 100 feet below the horizon of C 3, different section; about 250 feet below C 8, same section.

Lower Cambrian: Slaty black limestones in the lower part of the Man-t'o shales [Blackwelder, 1907, p. 28 (third paragraph), and fig. 8 (bed 11), p. 28], 3.5 miles (5.6 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

One species, *Redlichia* sp.

C 61. About 25 feet above C 6, same section; about 125 feet below C 64, same section; about same horizon as C 11, different section.

Upper Cambrian: A dense black limestone in the uppermost limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 41 (third list of fossils), and fig. 10 (bed 13), p. 38], 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung. This horizon is at the lower of the two stars opposite bed "13" on page 38.

Billingsella pumpellyi
Proampyx burea
Pterocephalus busiris
Chuangia batia
Chuangia fragmenta
Ptychaspis baubo

C 62. About 75 feet above C 1, which occurs at a locality 3 miles east; about 75 feet below C 12 and C 13, same section.

Middle Cambrian: Earthy layer in the middle limestone of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 40 (last list of fossils, and fig. 10 (base of bed 7), p. 38], 2.5 miles (4 km.) south of Yen-chuang, on the north-northeast spur of Hu-lu-shan, Sin-t'ai district, Shan-tung.

Obolus chinensis
Acrotreta shantungensis
Hyolithes cybele
Anomocarella chinensis

C 63. About 40 feet above C 5, same section; about 25 feet below C 9, same section.

Middle Cambrian: Sandy shale near the base of the Kiu-lung group [Blackwelder, 1907, p. 37 (third paragraph), and fig. 8*a* (bed 32), p. 29], 3.5 miles (5.6 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

One species, *Obolus obscurus*.

C 64. About 125 feet above C 61, same section.

Upper Cambrian: Upper limestone member of the Kiu-lung group [Blackwelder, 1907, pp. 37 and 42 (first list of fossils), and fig. 10 (bed 20), p. 38], 2.7 miles (4.3 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung.

Obolus damesi
Eoorthis doris
Eoorthis kayseri
Eoorthis linnarssoni
Huenella orientalis
Syntrophia orthia
Hyolithes daphnis
Orthotheca cyrene
Solenopleura beroe
Chuangia batia
Chuangia nais
Ptychaspis baubo
Ptychaspis cacus
Ptychaspis callisto
Ptychaspis calyce
Ptychaspis ceto
Ptychaspis sp. undt. (free cheek)
Anomocare sp.
Coosia ? bianos

C 65 = *Ordovician.*

C 66. "Material probably lost." [Bailey Willis.]

C 67. Supposed to be from horizon of C 36, C 45, C 47, C 50, and C 68.
Upper Cambrian: Stream gravels (from the wash from the mountains south of the city) used in making the railroad grade one-third mile (0.5 km.) west of the west city gate at Tsi-nan, Shan-tung.

Obolus cf. *matinalis*
Eoorthis cf. *linnarssoni*
Ptychaspis sp. undt.

C 68. Same horizon as C 47 and C 50, same section; about same horizon as C 45, different section; below C 36, same section.
Upper Cambrian: Upper part of the Ch'au-mi-tién limestone [Blackwelder, 1907, p. 36 (part of the third list of fossils)], on crest of ridge east of Ch'au-mi-tién, 200 yards (183 m.) north of the wayside shrine, Ch'ang-hia district, Shan-tung.
Two species, *Eoorthis kayseri* and *Anomocarella ?* sp. undt.

C 69. 35 feet above C 70, same section; below C 71, same section.
Middle Cambrian: Limestone in shales about 65 feet (19.5 m.) above the base of the Ki-chóu limestone [Willis and Blackwelder, 1907, p. 145, first list of fossils], 4 miles (6.4 km.) east of Fang-lan-chön, Shan-si.

Conokephalina vesta
Inouyia inflata
Agraulos obscura
Anomocare nereis
Dolichometopus hyrie

C 70. 35 feet below C 69, same section.
Middle Cambrian: Oolitic limestone about 30 feet (9 m.) above the base of the Ki-chóu limestone [Blackwelder, 1907, p. 144, last list of fossils], 4 miles (6.4 km.) south-southwest of Tung-yü, Shan-si.

Scenella ? dilatatus
Helcionella ?? simplex
Conokephalina maia
Conokephalina sp.
Inouyia capax
Inouyia melie
Agraulos vicina

C 71. About 50 feet below the horizon of C 37 and C 72, same section; about 125 feet above C 75, different section.
Middle Cambrian: Massive cliff-making limestone in the central portion of the Ki-chóu formation [Willis and Blackwelder, 1907, pp. 139 and 145 (second list of fossils)], 4 miles (6.4 km.) southwest of Tung-yü, Shan-si.

Obolus shansiensis ?
Yorkia ? orientalis
Acrotreta shantungensis
Eoorthis sp. undt.
Orthotheca glabra
Agnostus chinensis
Dorypyge richthofeni lævis
Crepicephalus damia
Solenopleura pauperata
Anomocarella bigsbyi
Anomocarella comus
Anomocarella undata

C 72. About same horizon as C 37, same section; about 50 feet above C 71, same section; about 200 feet below C 73, same section; about 225 feet below C 74, same section.

Middle Cambrian: Thin green-gray limestone interbedded with ocherous and green clay shales, overlying the massive oolite in the Ki-chóu formation [Willis and Blackwelder, 1907, pp. 139 and 145 (third list of fossils)], 4 miles (6.4 km.) east of Fang-lan-chön, Shan-si.

Lingulella (*Lingulepis ?*) sp. undt.	*Dorypyge richthofeni lævis*
Pelagiella willisi	*Conokephalina* sp. undt.
Orthotheca glabra	*Anomocare flava*
	Anomocare ? nereis

C 73. About 200 feet above C 37 and C 72, same section; about 25 feet below C 74, same section.

Middle Cambrian: Conglomeritic limestones near the top of the Ki-chóu formation [Willis and Blackwelder, 1907, p. 145, fourth list of fossils], 4 miles (6.4 km.) east of Fang-lan-chön, Shan-si.

Two species, *Blackwelderia cilix* and *Inouyia ? regularis.*

C 74. About 225 feet above the horizon of C 37 and C 72, same section; about 25 feet above C 73, same section.

Upper Cambrian: A dense blue dolomite limestone at the top of the Ki-chóu limestone [Willis and Blackwelder, 1907, pp. 139 and 145 (fifth list of fossils)], 4 miles (6.4 km.) east of Fang-lan-chön, Shan-si.

Two species, *Eoorthis kayseri* and *Ptychaspis bella.*

C 75. About 125 feet below C 71, different section.

Middle Cambrian: Limestone near the base of the Ki-chóu formation [Willis and Blackwelder, 1907, p. 143], 4.5 miles (7.2 km.) south of Wu-t'ai-hién, Shan-si.

Coscinocyathus elvira	*Inouyia armata*
Obolus obscurus	*Inouyia melie*
Eoorthis kichouensis	*Agraulos nitida*
Ptychoparia lilia	*Agraulos uta*

C 76. (Indeterminate fragments only.)

C 77. *Middle Cambrian*: Limestone interbedded in green shales not more than 300 feet (90 m.) above the Man-t'o shales [Willis and Blackwelder, 1907, p. 144, first list of fossils], 4 miles (6.4 km.) southeast of Yau-t'o, near Wu-t'ai-hién, Shan-si.

Lisania cf. *bura*	*Anomocarella irma*
Anomocare sp. undt.	

Manchurian Localities

All of the collections from Manchuria came from Tschang-hsing-tau Island, east of Niang-niang-kung, in the southwestern section of the Province of Liau-tung. The general stratigraphic relations of the section are given by Blackwelder [1907, p. 92] and the detailed section of Iddings on page 56 of this memoir.

The collections were made by Prof. Joseph P. Iddings and his Chinese interpreter Li San, in September, 1909.

35 n. *Middle Cambrian: Fu-chóu series.* Limestones near the base of the series just above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria. [Field locality No. 4; 1 = 36*c*, 2 = 35*r*, 4 = 35*n*, 5 = 36*d*, and 6 = 36*e*, are stated by Mr. Iddings to be very nearly the same horizon and at the same locality. They are the lowest fossils found.]

Protospongia chloris
Protospongia sp. undt.
Micromitra sculptilis
Micromitra (Paterina) lucina
Micromitra (Iphidella) pannula maladensis
Micromitra (Iphidella) pannula ophirensis
Obolus chinensis
Obulus damesi
Acrothele matthewi eryx
Acrotreta shantungensis
Hyolithes cybele
Orthotheca cyrene
Orthotheca delphus
Orthotheca glabra
Agnostus chinensis
Dorypyge richthofeni
Ptychoparia kochibei
Pterocephalus liches
Solenopleura beroe
Agraulos sorge
Solenopleura sp. undt.
Anomorcare ephori
Anomocare latelimbatum
Anomocare megalurus
Anomocare minus
Anomocare minus var.
Anomocare subquadratum
Anomocarella chinensis
Anomocarella hermias
Anomocarella macar
Anomocarella temenus
Anomocarella cf. *temenus*

35 o. About 50 feet higher than 35*p*; about the same horizon as 36*h*; see 36*g*. *Middle Cambrian: Fu-chóu series.* Shales about 130 feet (40 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations]; collected in drainage cuts a short distance back from the bluff (see 35*n*) forming the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Obolus damesi
Acrothele matthewi eryx
Acrotreta shantungensis
Agnostus chinensis
Damesella sp. undt.
Ptychoparia typus
Dolichemotopus deois
Bathyuriscus manchuriensis

35 p. About 80 feet above 35*n*; about 50 feet below 36*h*.
Middle Cambrian: Fu-chóu series. Shales about 80 feet (24 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Linguella manchuriensis
Acrotreta pacifica
Agnostus chinensis
Dorypyge richthofeni
Dolichometopus deois

35 q. About 70 feet higher than 36*h*; about 800 feet below 36*f*.

Middle Cambrian: Fu-chóu series. About 200 feet (61 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Protospongia chloris
Lingulella marcia
Acrotreta venia
Damesella blackwelderi
Anomocare lisania

35 r. Very nearly same horizon as 35*n*.

Middle Cambrian: Fu-chóu series. Limestones near the base of the series just above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations], collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Manchuria.

Micromitra sculptilis
Micromitra (Paterina) lucina
Micromitra (Iphidella) pannula maladensis
Obolus damesi
Obolus shansiensis
Acrothele matthewi eryx
Acrotreta shantungensis
Hyolithes cybele
Orthotheca delphus
Agnostus chinensis
Dorypyge richthofeni
Ptychoparia kochibei
Crepicephalus convexus
Solenopleura agno
Solenopleura chalcon
Anomocare ephori
Anomocarella chinensis
Anomocarella temenus
Dolichometopus deois
Asaphiscus iddingsi

36 c. Very nearly same horizon as 35*n*.

Middle Cambrian: Fu-chóu series. Limestones near the base of the series just above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

No identifiable species.

36 d. Very nearly same horizon as 35*n*.

Middle Cambrian: Fu-chóu series. Shales near the base of the series just above the white quartzite [see Blackwelder, 1907, p. 92, for general section giving stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Micromitra (Paterina) lucina
Obolus damesi
Acrothele matthewi eryx

36 e. Very nearly same horizon as 35*n*.

Middle Cambrian: Fu-chóu series. Shales interbedded with limestones near the base of the series just above the white quartzite [see Blackwelder, 1907, p. 92, for general section showing stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Obolus damesi
Acrothele matthewi eryx
Agnostus chinensis
Ptychoparia kochibei
Anomocare minus
Anomocare minus var.
Asaphiscus iddingsi

36 f. About 800 feet above 35*q*; the highest horizon.

Middle Cambrian: *Fu-chóu series.* About 1,000 feet (305 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Planolites (annelid trails)
Lingulella ? marcia
Agnostus douvilléi
Albertella pacifica
Teinistion typicalis
Stephanocare sinensis
Blackwelderia sinensis
Damesella blackwelderi
Drepanura premesnili
Liostracina krausei
Shantungia spinifera

36 g. About 50 feet higher than 35*p*; about same horizon as 36*h*; see 35*o*.

Middle Cambrian: *Fu-chóu series.* Shale about 130 feet (40 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section showing stratigraphic relations]; collected in drainage cuts a short distance back from the bluff (see 35*n*) forming the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Obolus damesi
Acrothele matthewi eryx
Acrotreta shantungensis
Orthotheca cf. *delphus*
Agnostus chinensis
Anomocarella chinensis
Bathyuriscus manchuriensis

36 h. About 70 feet below 35*q*; about 50 feet above 35*p*; 36*g* and 35*o* are from approximately the same section.

Middle Cambrian: *Fu-chóu series.* Shales about 130 feet (40 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section showing stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

Obolus damesi
Lingulella marcia
Acrotreta shantungensis
Agnostus chinensis
Anomocare minus
Bathyuriscus manchuriensis

36 i. Below 35*q*; above 36*h*.

Middle Cambrian: *Fu-chóu series.* Approximately 175 feet (53 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section showing stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

36 j. Above 35*q*; below 36*f*.

Middle Cambrian: *Fu-chóu series.* Approximately 175 feet (53 m.) above the white quartzite [see Blackwelder, 1907, p. 92, for general section showing stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria.

LIST OF ALL SPECIES FROM LIAU-TUNG, MANCHURIA, WITH LOCALITY NUMBERS

Protospongia chloris Walcott (35*n* Limestone) (35*q*).
Protospongia sp. undt. (spicules) (35*n* Limestone).
Planolites (annelid trails) (36*f* Limestone and shale).
Micromitra sculptilis Meek (35*n*) (35*r* Limestone).
Micromitra (*Paterina*) *lucina* Walcott (35*n*) (35*r* Limestone) (36*d*).
Micromitra (*Iphidella*) *pannula maladensis* Walcott (35*n*) (35*r* Limestone).
Micromitra (*Iphidella*) *pannula ophirensis* Walcott (35*n* Limestone).
Obolus chinensis Walcott (35*n* Limestone).
Obolus damesi Walcott (35*n* Limestone) (35*o*) (35*r*) (36*d*) (36*e* Shale) (36*g*) (36*h* Shale).
Obolus shansiensis Walcott (35*r* Limestone).
Lingulella manchuriensis Walcott (35*p* Shale).
Lingulella marcia Walcott (35*q*) (? 36*f* Limestone and shale) (36*h* Shale).
Acrothele matthewi eryx Walcott (35*n* Limestone) (35*o*) (35*r*) (36*a*) (36*e* Shale) (36*g*).
Acrotreta pacifica Walcott (35*p* Shale)
Acrotreta shantungensis Walcott (35*n* Limestone) (35*o*) (35*r*) (36*g*) (36*h* Shale).
Acrotreta venia Walcott (35*q*).
Hyolithes cybele Walcott (35*n* Limestone) (35*r*).
Orthotheca cyrene Walcott (35*n* Limestone).
Orthotheca delphus Walcott (35*n* Limestone) (35*r*).
Orthotheca cf. *delphus* Walcott (36*g*).
Orthotheca glabra Walcott (35*n* Limestone).
Agnostus chinensis Dames (35*n* Limestone) (35*o*) (35*p*) (35*r*) (36*e* Shale) (36*g*) (36*h* Shale).
Agnostus douvilléi Bergeron (36*f* Limestone and shale).
Albertella pacifica Walcott (36*f* Limestone and shale).
Dorypyge richthofeni Dames (35*n*) (35*p* Shale) (35*r* Limestone).
Teinistion typicalis Walcott (36*f* Limestone and shale).
Stephanocare sinensis Bergeron (36*f* Limestone and shale).
Blackwelderia sinensis Bergeron (36*f*).
Damesella blackwelderi Walcott (35*q*) (36*f* Limestone and shale).
Damesella sp. undt. (35*o*).
Drepanura premesnili Bergeron (36*f* Limestone and shale).
Ptychoparia kochibei Walcott (35*n*) (35*r* Limestone) (36*e* Shale).
Ptychoparia typus Dames (35*o*).
Crepicephalus convexus Walcott (35*r* Limestone).
Liostracina krausei Monke (36*f* Limestone and shale).
Pterocephalus liches Walcott (35*n* Limestone).
Shantungia spinifera Walcott (36*f* Limestone and shale).
Agraulos sorge Walcott (35*n* Limestone).
Solenopleura agno Walcott (35*r* Limestone).
Solenopleura beroe Walcott (35*n* Limestone).
Solenopleura chalcon Walcott (35*r* Limestone).
Solenopleura sp. undt. (35*n* Limestone).
Anomocare ephori Walcott (35*n*) (35*r* Limestone).

Anomocare latelimbatum Dames (35*n* Limestone).
Anomocare lisani Walcott (35*q*).
Anomocare megalurus Dames (35*n* Limestone).
Anomocare minus Dames (35*n* Limestone) (36*e* Shale) (36*h*).
Anomocare minus Dames var. undt. (35*n* Limestone) (36*e* Shale).
Anomocare subquadratum Dames (35*n* Limestone).
Anomocarella chinensis Walcott (35*n*) (35*r* Limestone) (36*g*).
Anomocarella hermias Walcott (35*n* Limestone).
Anomocarella macar Walcott (35*n* Limestone).
Anomocarella temenus Walcott (35*n* Limestone) (35*r*).
Dolichometopus deois Walcott (35*o*) (35*p* Shale) (35*r* Limestone).
Bathyuriscus manchuriensis Walcott (35*o*) (36*g*) (36*h* Shale).
Asaphiscus iddingsi Walcott (35*r* Limestone) (36*e*).

GEOLOGICAL CONDITIONS

PRE-CAMBRIAN CONTINENTAL CONDITIONS

The material composing the surface of the land that was awaiting the advance of the Cambrian sea must have been, as described by Willis, very largely made up of clays and sands resulting from the long disintegration of the continental surface at a relatively low relief. Applying this conclusion, we infer that the Asiatic continent at the beginning of Cambrian time was practically a featureless continent and that the transgressing Cambrian sea gradually rose, carrying with it the marine life that developed in the sea on the continental slopes during the long period in which the pre-Cambrian continental surface had been worn down nearly to base-level.

If we now turn to the life contained in the first series of deposits, the Man-t'o formation, we find that it represents the closing epoch of Lower Cambrian time that succeeded the faunas of the *Olenellus* epoch of the older western American formations, and the traces of the Lower Cambrian fauna that have been found in Siberia. The presence of a portion of the later Lower Cambrian fauna in Siberia indicates that this portion of the Asiatic continent was at a lower level and hence was traversed at an earlier epoch by the Cambrian sea than the portions of southeastern and southern Asia, which include Manchuria, eastern and southern China, and northern India.

The relations of the Cambrian strata to the subjacent rocks compel the conclusion that the Asiatic continent was a land surface during the earlier part of Cambrian time and during the long Lipalian interval,[1] represented by the deposition of the great series of pre-Cambrian sedimentary rocks on the North American conti-

[1] Walcott, C. D. Smithsonian Misc. Coll., Vol. 57, Cambrian Geology and Paleontology, No. 1, 1910, Abrupt appearance of the Cambrian fauna on the North American continent, p. 14.

VIEW IN LATERAL CANYON OF THE O-SHUI-HO,

Showing unconformity between the pre-Cambrian Si-t'ai schists (Ws) and Cambrian shale (€m), near Yen-t'óu in the Wu-t'ai-shan, Province of Shan-si. (After Willis, Research in China, Pub No. 54. Carnegie Institution of Washington, Vol. 1, Pt. 1, 1907, Pl. 19, p. 140.)

nent and the lesser series on the Asiatic continent, described by Willis[1] as the Wu-t'ai and the Hu-t'o systems.

In speaking of the rocks of the Hu-t'o system he says:

> All of the rocks of the Hu-t'o system are sedimentary strata; conglomerate; quartzite, shale, and limestone, which resemble the unmetamorphosed Paleozoic rocks more nearly than they do the Wu-t'ai schists. The physical events which intervened between the close of the Wu-t'ai period and the beginning of the Hu-t'o involved greater changes and probably longer time than those which occurred after the Hu-t'o and before the Sinian; but the presence of a rich fauna in the Sinian seas distinguishes that period from the preceding time, during which the life forms, though probably numerous, did not generally become fossil. The nearest relations of the Hu-t'o system are with the Belt terrane of Montana (in America), and it is probable that pre-Cambrian fossils[2] such as have been found in the Belt may eventually be discovered in the Hu-t'o.[3]

In the above-quoted paragraph Doctor Willis unconsciously gives a strong argument for the non-marine origin of the rocks of the Hu-t'o system when he says that the presence of a rich fauna in the Sinian seas distinguishes that period from the preceding (Hu-t'o) time. It was the absence of marine life and the character of the sediments that led me to conclude that there were no marine deposits on the North American continent (nor probably on any of the continents) representing the Lipalian interval or the interval between the fossiliferous Cambrian formations and the period of the development of the early pre-Cambrian marine life along the shores of the continents.[4]

I now anticipate that if the rocks of the Wu-t'ai and Hu-t'o systems are studied with the view that they may not be of marine origin, they will be found deposited as epicontinental sediment accumulated on flood plains or in bodies of fresh water. In part they are more altered and metamorphosed than the pre-Cambrian sedimentary rocks of North America, and hence it may be more difficult to determine their origin.

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[1] Willis, Bailey. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, pp. 4-20.

[2] Pre-Cambrian fossiliferous formations, C. D. Walcott, Bull. G. S. A., Vol. 10, p. 199, 1899.

[3] Willis, Bailey. Research in China, Vol. 2, 1907, Systematic geology, p. 7.

[4] Walcott, C. D. Smithsonian Misc. Coll., Vol. 57, Cambrian Geology and Paleontology, No. 1, 1910, Abrupt appearance of the Cambrian fauna on the North American continent, pp. 14, 15.

UNCONFORMITY AT BASE OF CAMBRIAN

Dr. Bailey Willis has given a very clear and full description of the Sinian system, the lower portion of which is referred to the Cambrian.[1] He found the unconformity at the base of the Sinian that divided the Paleozoic from the pre-Cambrian to be a break of the first magnitude even where the underlying strata are the Ta-yang (Nan-k'óu) limestone of the late Proterozoic.[2]

> The mechanical sediment of the basal formation has the character of a fine alluvium and is of uniform moderate thickness, 350 to 500 feet, 105 to 150 meters. The material is red soil, particles of ferruginous clay being thoroughly oxidized and grains of sand coated with ferric oxide. The plane of contact at the base is sharply defined, usually very even, not broken by abrupt hollows or decided projections, but swelling gently over rounded bosses of the harder rocks. Pebbles of the subjacent rocks are wanting in the basal deposits, as a rule, and where they occur are limited to very local accumulations. Beds of arkose have not been seen, nor even beds of clean sand such as waves usually spread. Thus none of the effects of violent breakers are present; the evidence is that a gentler agent cleaned the surface of the ancient rocks. The facts support the view that the lowest strata of the Man-t'o formation were laid down in the shallows, lagoons, and flood-plains of a very low, flat coast, where weak waves, feeble shore currents, and rivers interacted.[3]

In discussing the unconformity at the base of the Sinian, Doctor Willis states that each unconformity is somewhere represented by continuous, conformable deposits, and the area of unconformity is bounded by the areas of conformity:

> When we pass from one to the other there is difficulty in dividing the continuous series of strata at a plane corresponding to that indicated by the discontinuity in the neighboring series. This condition exists at the base of the Cambrian in certain localities in the United States, where the lowest fossiliferous Cambrian strata are conformably underlain by great thicknesses of sediments, that accumulated in the depressions from which the Cambro-Ordovician epicontinental sea expanded. Such sediments are by some regarded as pre-Cambrian, by some as the downward extension of the Cambrian. There is no difference of opinion regarding the base in sections where the unconformity intervenes, as is commonly the case.[4]

Since Willis wrote the above in 1907, I have completed my study of the relations of the Cambrian and pre-Cambrian in North America and have concluded that the pre-Cambrian unconformity is universal in all known localities of Cambrian sedimentation and that the depressions in which the pre-Cambrian sediments were deposited

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[1] Willis, Bailey. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, pp. 35, 49.

[2] Idem, p. 31.

[3] Idem, p. 32.

[4] Idem, p. 35.

were epicontinental, mainly non-marine, and in no way connected directly with the subsequent Cambrian sedimentation.[1]

THE GEOLOGIC FORMATIONS

Lower Sinian, Man-t'o Shale

The basal formation, the Man-t'o, is a red shale that passes often into red or chocolate-brown shaly sandstone, and this is interbedded with thin, sometimes persistent, layers of gray, cream-colored limestone. The thickness varies from 350 to 500 feet (105 to 150 meters). The basal layers occasionally show local conglomerates. The calcareous layers of the Man-t'o occur occasionally near the base, persistently at horizons 100 to 150 feet (30 to 45 meters) higher up, and again less commonly near the top, which is often sandy. The transition into the overlying limestone of the Kiu-lung group is formed of interbedded brown shales and gray limestones.

The interbedding of the shale and limestone is irregular. It is apparent that local conditions were unlike in adjacent waters at any one time and varied in unlike manner from time to time, but red sediment from the land or calcareous sediment from the sea was deposited at any time, as stated by Willis,[2] who also says:

> One may form a concept of the conditions somewhat as follows: Along the flat, red shore of the Man-t'o sea, bars and islands formed where streams emptied, and shut off the mud-carrying currents from intermediate stretches of coast. More or less extensive lagoons were thus produced and within these the waters were clear. Being partly closed and shallow, they were relatively warm and liable to maximum evaporation. Rippling of the surface favored precipitation of lime carbonate by agitation. Warmth and protection invited organic life, both plant and animal, which probably occupied the lagoons in low forms that did not become fossil before trilobites, the earliest that have been preserved, discovered the habitat.
>
> The description of the Man-t'o formation has thus far dealt with it as it is developed in northern China. The red mud does not occur in the south on the Yang-tzï-kiang, where we saw the base of the Sinian, but the strata which we suppose to be equivalent are thin-bedded gray limestones which rest on a well-defined glacial till.[3]

The geological conditions thus briefly outlined clearly indicate that the Man-t'o formation was the first deposit made over a wide

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[1] Walcott, C. D. Smithsonian Misc. Coll., Vol. 57, Cambrian Geology and Paleontology, No. 1, 1910, Abrupt appearance of the Cambrian fauna on the North American continent, pp. 2-3.

[2] Willis, Bailey. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, p. 38.

[3] Idem, pp. 38-39.

area by the slowly transgressing Cambrian sea. This area is outlined by Willis on his map of "Southern Asia during the Sinian period."[1]

Middle Sinian, Kiu-Lung Group

Willis describes this group in the following words:

> The Kiu-lung group of Shan-tung is a succession of limestones and shales which immediately follows the Man-t'o formation. Transition beds connect the two. Shale is a common rock in both, but in the Man-t'o it is red, whereas in the Kiu-lung it is green. Limestone is thin-bedded and subordinate in the former; in the latter it is usually massive and predominant. The Man-t'o contains a sparse Middle or Lower Cambrian fauna in its upper portion; the Kiu-lung carries very abundant faunas, which range from Middle Cambrian at the base to Upper Cambrian and possibly to lowest Ordovician at the top.[2]

The Kiu-lung group is divided into the Ch'ang-hia limestone at the base, the Ku-shan shale, and the Ch'au-mi-tién limestone.

Ch'ang-hia limestone.—The lower portion of the Kiu-lung group is composed of green shale and limestone, alternating in character and forming a series 400 to 500 feet thick (120 to 150 meters).

Ku-shan shale.—The upper portion of the group is characterized by dominance of shale, and Doctor Willis gave it the name of the Ku-shan shale in the vicinity of Shan-si, where a single stratum occurs 150 feet (45 meters) thick.

Ch'au-mi-tién limestone.—The upper part of the Kiu-lung group, the Ch'au-mi-tién limestone, horizontally maintains a uniform character. It is given a thickness of from 400 to 600 feet (120 to 185 meters). It represents a widespread condition of deposition.

The Upper Sinian, the Tsi-nan limestone, differs in lithologic characters and also contains fossils of Lower Ordovician type.[3]

The lower portion of the Kiu-lung group is designated as the Ch'ang-hia limestone in the Ch-ang-hia district, and in the Sin-t'ai district as the lower limestone. Blackwelder gives the reason for this as follows:

> The classification of the Kiu-lung group into three separate divisions is not appropriate for this district, in spite of the fact that the general paleon-

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[1] Willis, Bailey. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, pl. 4.

[2] Idem, p. 40.

[3] The Cambrian portion of the Sinian is described in detail with sections and distributions of faunas by Dr. Eliot Blackwelder in his description of the stratigraphy of Shan-tung [Blackwelder, Stratigraphy of Shan-tung, 1907, Vol. 1, part 1, pp. 19-58], and in the description of the stratigraphy of Chï-li in Shan-si [Reconnaissance in southwest Liau-tung, 1907, pp. 136-147], so that it will not be necessary for me to go further into the details of sedimentation and stratigraphy.

VIEW OF CLIFFS AND SLOPE OF ALGONKIAN AND CAMBRO-ORDOVICIAN STRATA ON SOUTH BANK OF THE RIVER,

Showing the location of the glacial deposit with reference to the overlying strata. It is very probable that the glacial deposit is of Algonkian age. €nq = quartzite at the base of Nan-t'ou formation; €nt = layer of glacial till 120 feet (37 m.) thick; €Oks = Ki-sin-ling limestone. Nan-t'ou on the Yang-tzi, Province of Shen-si. (After Willis, Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, Pt. 1, 1907, Pl. 37, A, p. 268.)

tologic horizons of the Ch'ang-hia area are recognized here with ease. The black oolite is much reduced in thickness, and is largely replaced by shales. The Ku-shan shale is thicker and carries fossils which belong to the Ch'ang-hia and Ch'au-mi-tién formations, respectively, in its upper and lower portions. The Ch'au-mi-tién limestone alone retains the general character noted in the first area studied, but its base is somewhat shifted. Thus, the Kiu-lung, which in the Ch'ang-hia district is a group composed of three formations, is in the Sin-t'ai district a consistent formation, containing members of limestone and shale, which are of local occurrence only.[1]

RELATION OF THE CAMBRIAN TO THE ORDOVICIAN

The Ch'au-mi-tién limestone is described by Blackwelder as a very dark gray, finely crystalline rock that has a distinctly blue color where exposed to the weather. The summit of the formation is marked by a change in the character of the sediments, the lower member of the next younger series being yellowish in color and notably dolomitic.[2]

The Tsi-nan formation above the Cambrian is one of the most widely distributed formations in China and is readily recognized by the light-colored argillaceous limestones or dolomites and thin shales of its lower member and the brown dolomitic limestone of its upper member.[3]

The Tsi-nan formation is referred to the Ordovician on the evidence of fossils found in its upper member. No fossils were found in the lower portion.[4]

The transition from the Upper Cambrian to the Tsi-nan formation is not marked by an unconformity, but the introduction of argillaceous and dolomitic limestones indicates a change in sedimentation that was brought about by diastrophic action that revived erosion and ultimately led to the great epeirogenic changes that marked the close of the Sinian. The fauna of the Cambrian disappeared, so far as known, everywhere in the western Pacific Province and the faunas of Ozarkian[5] and Canadian time did not flourish in the Tsinan sea, and apparently entered it only at rare intervals. It may be that faunas corresponding to the Lake Champlain and Mississippi

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[1] Blackwelder, Eliot. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, Pt. 1, 1907, Stratigraphy of Shan-tung, pp. 36-37.

[2] Idem, pp. 34, 35.

[3] Idem, p. 44.

[4] Idem, pp. 44-46.

[5] Ulrich, E. O. Bull. Geol. Soc. America, Vol. 22, 1911, Revision of the Paleozoic systems, p. 627.

Valley Canadian and Ozarkian will be found on the Asiatic continent, but at present we must be content to close the Cambrian with the upper horizon of the Kiu-lung group, and wait for further data on the faunas of the Tsi-nan formation and their relation to the Cambrian and Lower Ordovician faunas of North America and Europe.

The presence of the genera *Syntrophia, Huenella, Cyrtoceras,* and *Tsinania* in the Ch'au-mi-tién limestone proves that the Upper Cambrian fauna was beginning to assume a post-Cambrian aspect toward the close of the deposition of the Ch'au-mi-tién limestone. It is quite possible that the fauna of the lower portion of the Tsi-nan formation, when found, will have an Upper Cambrian aspect, but it is more probable that it will have the general facies of that of the lower Pogonip of the Nevada Cordilleran sections.[1]

At present the trilobite fauna of the Upper Cambrian in the Pacific and Cordilleran provinces is readily recognizable at nearly all localities by the presence of such genera of trilobites as *Ptychaspis, Tsinania* and various genera of the Ptychoparidæ. *Dikelocephalus* is restricted in geographic distribution to a few localities in North America. I would place the formations containing a typical Cambrian trilobitic fauna in the Cambrian, and where a formation has a fauna characterized by a new group of forms that evidently belong to a later fauna it should be assigned to a post-Cambrian system even though it may have a few Cambrian genera of trilobites included in it.

In North America we find that the fauna of the Upper Cambrian in the Cordilleran region is quite distinctly marked by the presence of typical Cambrian genera and the absence of typical post-Cambrian genera. In the central area between the Rocky Mountains and the Appalachians the Upper Cambrian fauna as characterized by the trilobitic genera *Agnostus, Ptychaspis, Dikelocephalus, Ptychoparia,* and *Tsinania* is singularly free from commingling of typical post-Cambrian genera except in the case of the Eminence[2] fauna, where a few trilobitic genera have persisted into Ozarkian time.[3]

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[1] Walcott, C. D. Bull. U. S. Geol. Survey, No. 10, 1884, On the Cambrian faunas of North America; Preliminary studies, p. 3.

[2] By error the Gasconade fauna was inserted in this place. The Gasconade is a later fauna. Neither the Eminence nor the Gasconade fauna includes the genus *Dikelocephalus.*

[3] Ulrich, E. O. Bull. Geol. Soc. America, Vol. 22, 1911, Revision of the Paleozoic systems, p. 631.

TSINANIA, new genus

Cranidium subrhomboidal in outline; moderately convex; slight traces of an occipital ring at base of glabella. Palpebral lobes just back of the center of the cranidium, and of medium size. Postero-lateral limbs subtriangular, short. Facial sutures curving inward so as to give a rounded front to the cranidium.

Surface smooth or minutely punctate.

Associated pygidia of species referred to the genus a little broader than long and with a slightly defined, narrow, long median lobe marked by obscure transverse furrows that may be faintly outlined on the broad lateral lobes.

Genotype.—Illænurus canens Walcott.[1]

Stratigraphic range.—Upper Cambrian of eastern China. Lower portion of Ch'au-mi-tién limestone. Also Notch Peak formation, western Utah.

Geographic distribution.—Provinces of Shantung, China. Western Utah in House Range of Cordilleran Province of western America.

Observations.—The genus *Tsinania* differs from *Illænurus* Hall in having the cranidium rounded in front by the incurving of the facial sutures and short, postero-lateral limbs. The associated pygidia of the three species from China are nearly as long as wide and quite unlike the short, transverse pygidium of *Illænurus*. From *Symphysurus* Goldfuss, it differs in its smaller palpebral lobes, rounded front of the cranidium and the central portion of the cranidium, which is well defined and expanded anteriorly in *Symphysurus* and obscure and rounded inward in *Tsinania*.

The species referred to the genus are: *Tsinania canens* (Walcott),[2] *Tsinania ceres* (Walcott),[2] *Tsinania cleora* (Walcott),[3] and *Tsinania dictys* (Walcott).[2]

PALEONTOLOGY

STRATIGRAPHIC AND GEOGRAPHIC DISTRIBUTION OF SPECIES

The table gives the general stratigraphic and geographic distribution of the Chinese species described in this memoir. The asterisk used opposite the species by authors to indicate the position of the

[1] Research in China, Carnegie Institution of Washington, Publication No. 54, Vol. III, 1913, p. 222, pl. 23, fig. 3.

[2] Idem, pp. 222-224.

[3] *Illænurus* Walcott. Smithsonian Misc. Coll., Vol. 53, 1908, p. 175, 1*a* of Notch Peak formation of the Upper Cambrian, House Range, Utah.

species is replaced by the locality number or numbers to enable the student to refer to the exact locality, stratigraphic position, and lists of associated species. [See pp. 17-34 for list of localities and associated species.]

The following is a summary of the genera and species:

Classification.	Genera.	Subgenera.	Species.	Varieties.
Foraminifera....	1	....	1	....
Porifera	2	....	2	....
Anthozoa	1	....	1	....
Annelida	1	....	1	....
Brachiopoda.....	13	4	36	4
Gastropoda	5	....	11	2
Pteropoda	2	....	11	1
Cephalopoda	1	....	1	....
Trilobita	36	1	175	4
Ostracoda	1	....	6	....
	63	5	245	11

General Stratigraphic and Geographic Position of the Cambrian Faunas of China

Name.	Stratigraphic position. Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	General geographic position. Near Yen-chuang.	Near Wu-t'ai-hién.	Tschang-hsing-tau Island.
FORAMINIFERA.						
Globigerina ? mantoensis	......	×	......	C 5	....	....
PORIFERA.						
Protospongia chloris	......	×	......	C 1 C 2 C 4	......	35n 35q
Protospongia sp. undt	......	×	......	......	....	35n
ANTHOZOA.						
Coscinocyathus elvira	......	×	......	....	C 75	....
ANNELIDA.						
Planolites sp. undt	......	×	......	....	....	36f
BRACHIOPODA.						
Micromitra sculptilis	......	×	......	....	....	35r 35n
Micromitra (Paterina) labradorica orientalis......	......	×	......	C 9	....	....
Micromitra (Paterina) lucina	......	×	......	....	....	35n 35r 36d
Micromitra (Iphidella) pannula maladensis*........	......	×	......	....	....	35n 35r
Micromitra (Iphidella) pannula ophirensis†........	......	×	......	C 5	....	35n
Obolus chinensis	......	×	......	C 62	....	35n

* Also occurs in Idaho and Newfoundland. † Also occurs in Utah.

NOTE.—The columns "Near Ch'ang-hia," "Near Ch'au-mi-tién," "Near Sin-t'ai-hién," "Near Tsi-nan," "Near Fang-lan-chön," "Near Tung-yü," "Near Chön-ping-hién," "Near Ting-hiang-hién," and "Near Kao-kia-p'u" are omitted in this page, as the species recorded in the first column were not collected in those localities.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China—Continued

Name.	Stratigraphic position.			General geographic position.										
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Wu-t'ai-hién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Near Chön-p'ing-hién.	Near Ting-hiang-hién.	Near Kao-kia-p'u.	Tschang-hsing-tau Island.
BRACHIOPODA—Continued.														
Obolus damesi		×			C 7, C 10, C 64									35*n*, 35*o*, 35*r*, 36*d*, 36*e*, 36*g*, 36*h*
Obolus matinalis ?			×					C 54, C 67 ?						
Obolus minimus		×			C 1									
Obolus obscurus		×			C 63		C 75							
Obolus shansiensis		×								C 71 ?	C 32	C 37		35*r*
Obolus (Westonia) blackwelderi		×			C 1, C 2, C 6									
Obolus (Westonia) sp. undt.			×					C 56						
Lingulella manchuriensis		×												35*p*
Lingulella marcia		×												35*q*, 36*f* ?, 36*h*
Lingulella (Lingulepis) eros		×			C 7									
Lingulella (Lingulepis ?) sp. undt.		×							C 72					
Dicellomus parvus		×			C 6						C 32			
Obolella asiatica	×			C 17							C 32′			
Yorkia ? orientalis		×								C 71				
Acrothele matthewi eryx		×			C 4									35*n*, 35*o*, 35*r*, 36*c*, 36*g*
Acrothele ? minuta		×			C 6									
Acrothele rara		×		C 23									C 57	
Acrotreta lisani		×		C 22										
Acrotreta pacifica		×		C 24 ?	C 1, C 2, C 4, C 5, C 12									35*p*
Acrotreta shantungensis		×			C 1 ?, C 62					C 71	C 32	C 37		35*n*, 35*o*, 35*r*, 36*g*, 36*h*
Acrotreta venia		×												35*q*
Discinopsis sulcatus			×					C 56						
Billingsella pumpellyi			×		C 61	C 36								
Billingsella richthofeni	×			C 20	C 3									
Eoorthis agreste		×		C 28										
Eoorthis doris			×		C 64									
Eoorthis kayseri			×		C 64	C 68			C 74					
Eoorthis kichouensis		×					C 75							
Eoorthis linnarssoni			×		C 64			C 67 ?						
Eoorthis pagoda			×					C 54, C 56						
Eoorthis sp. undt. (*a*)		×		C 26										
Eoorthis sp. undt. (*b*)		×								C 71				
Huenella orientalis			×		C 64									
Syntrophia orthia			×		C 64			C 54, C 56						

NOTE.—The column " Near Sin-t'ai-hién " is omitted in this page, as the species recorded in the first column were not collected in that locality.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China
—Continued

Name.	Stratigraphic position.			General geographic position.								
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Near Chön-p'ing-hién.	Near Kao-kia-p'u.	Tschang-hsing-tau Island.
GASTROPODA.												
Scenella clotho	....	×	....	C 18	....	....	....	....	....	......	....	....
Scenella ? dilatatus	....	×	....	......	....	....	....	....	C 70	......	....	....
Scenella sp. undt.	....	......	×	......	....	....	C 56	....	....	......	....	....
Matherella circe	....	......	×	......	....	....	C 56	....	....	......	....	....
Straparollina sp. undt.	....	×	....	......	....	....	C 55	....	....	......	....	....
Pelagiella chronus	....	×	....	C 18	C 1 C 4	....	....	....	....	......	....	....
Pelagiella clytia	....	......	×	......	....	C 47	....	....	....	......	....	....
Pelagiella pagoda	....	......	×	......	....	....	C 56	....	....	......	....	....
Pelagiella willisi	....	×	....	......	....	....	....	C 72	....	......	....	....
Helcionella ? clurius	....	×	....	......	....	C 46	....	....	....	......	....	....
Helcionella rugosa chinensis	×	......	....	......	C 3	....	....	....	....	......	....	....
Helcionella rugosa orientalis	....	......	....	C 18 C 21	....	....	....	....	....	......	....	....
Helcionella ?? simplex	....	×	....	......	....	....	....	....	C 70	......	..	....
PTEROPODA.												
Hyolithes cybele	....	×	....	C 22	C 1 C 2 C 4 C 62	....	....	....	....	......	....	35*n* 35r
Hyolithes daphnis	....	......	×	......	C 64	....	....	....	....	......	....	....
Hyolithes delia	×	......	....	......	C 3	....	....	....	....	......	....	....
Hyolithes sp. undt.	×	......	....	......	C 4?	....	....	....	....	C 32'	....	....
Orthotheca cyrene	....	×	×	......	C 64	C 47	....	....	....	......	....	35*n*
Orthotheca cyrene dryas	....	×	....	......	C 2	....	....	....	....	......	....	....
Orthotheca daulis	....	×	....	C 23	....	....	....	....	....	......	....	....
Orthotheca delphus	....	×	....	......	C 4	....	....	....	....	......	C 57	35*n* 35*r*
Orthotheca cf. delphus	....	×	....	......	....	....	....	....	....	......	....	36*g*
Orthotheca doris	....	×	....	......	....	....	....	....	....	C 32	....	....
Orthotheca glabra	....	×	....	......	....	....	....	C 72	C 71	......	....	35*n*
Orthotheca sp. undt.	....	......	×	......	....	....	C 56'	....	....	......	....	....
CEPHALOPODA.												
Cyrtoceras cambria	....	......	×	......	....	....	C 56	....	....	......	....	....
TRILOBITA.												
Agnostus chinensis	....	×	....	......	C 1 C 2 C 4	....	....	....	C 71	......	C 57	35*n* 35*o* 35*p* 35*r* 36*e* 36*g* 36*h*
Agnostus douvilléi	....	×	....	......	C 6	....	C 55	....	....	......	....	36*f*
Agnostus kushanensis	....	×	....	......	....	....	....	....	....	......	C 57	....
Agnostus parvifrons latelimbatus*	....	×	....	......	....	....	....	....	....	......	....	....
Microdiscus orientalis	....	×	....	......	....	....	....	....	....	C 32	....	....
Shumardia sp. undt.	....	×	....	......	....	C 51	....	....	....	......	....	....
Redlichia chinensis	×	......	....	C 15 C 16 C 27	....	....	....	....	....	......	....	....
Redlichia ? finalis	....	×	....	......	....	....	....	....	....	......	C 58	....
Redlichia nobilis	×	......	....	......	C 3	....	....	....	....	......	....	....
Redlichia sp. undt (*a*)	....	×	....	......	C 6	....	....	....	....	......	....	....
Redlichia sp. undt (*b*)	×	......	....	C 16	....	....	....	....	....	......	....	....
Redlichia sp. undt (*c*)	×	......	....	C 27	C 60	....	....	....	....	......	....	....
Albertella pacifica	....	×	....	......	....	....	....	....	....	......	....	....
Dorypyge bispinosa	....	×	....	......	C 2	....	....	....	....	......	....	....

* Occurs at Wang-tschuang, Shan-tung, China.

NOTE.—The columns "Near Sin-t'ai-hién," "Near Wu-t'ai-hién," and "Near Ting-hiang-hién," are omitted in this page, as the species recorded in the first column were not collected in these localities.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China
—Continued

Name.	Stratigraphic position.			General geographic position.									
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Sin-t'ai-hién.	Near Wu-t'ai-hién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Near Kao-kia-p'u.	Tschang-hsing-tau Island.
TRILOBITA—Continued.													
Dorypyge richthofeni		×		C 19, C 24, C 29, C 30	C 1							C 57	35n, 35p, 35r
Dorypyge richthofeni lævis		×								C 72	C 71		
Teinistion alcon		×			C 12								
Teinistion lansi *		×			C 6, C 12								
Teinistion typicalis		×			C 12								36f
Stephanocare ? monkei		×			C 6								
Stephanocare richthofeni		×			C 6				C 55				
Stephanocare ? sinensis		×			C 6								36f
Stephanocare ? sp. undt.		×			C 6								
Blackwelderia alastor		×			C 12								
Blackwelderia cilix		×							C 55	C 73			
Blackwelderia sinensis †		×			C 6								36f
Damesella bellagranulata		×			C 13								
Damesella blackwelderi		×			C 12, C 13, C 14, C 40								35q, 36f
Damesella brevicaudata		×		C 19									
Damesella sp. undt. (*c*)		×				C 46							35o
Drepanura ketteleri		×			C 6				C 55				
Drepanura premesnili		×			C 6				C 35				36f
Ptychoparia aclis	×			C 17, C 20, C 31									
Ptychoparia granosa	×			C 17									
Ptychoparia impar	×			C 17									
Ptychoparia impar var. ?		×			C 8								
Ptychoparia kochibei		×											35n, 35r, 36e
Ptychoparia ligea	×			C 31									
Ptychoparia lilia		×						C 75					
Ptychoparia ? tolus		×					C 52						
Ptychoparia typus		×											35o
Ptychoparia sp. undt.		×			C 4, C 5	C 48						C 58	
Ptychoparia (Emmrichella) bromus		×			C 6								
Ptychoparia (Emmrichella) constricta	×				C 3								
Ptychoparia (Emmrichella) eriopia		×		C 23									
Ptychoparia (Emmrichella) mantoensis	×			C 20, C 31									
Ptychoparia (Emmrichella) theano		×		C 23									
Conokephalina belus			×						C 56				
Conokephalina dryope			×						C 56				
Conokephalina maia		×									C 70		
Conokephalina vesta		×								C 69			
Conokephalina sp. undt.		×								C 72	C 70		
Crepicephalus convexus		×											35r
Crepicephalus damia		×		C 18, C 21, C 26							C 71		
Crepicephalus magnus		×		C 25?, C 18		C 48							
Lonchocephalus tellus		×			C 2								
Liostracina krausei		×			C 6								36f
Proampyx burea					C 61								

* Also from Yen-tsy-yai. † *Calymmene ? sinensis* Bergeron.

NOTE.—The columns " Near Chön-ping-hién " and " Near Ting-hiang-hién " are omitted in this page, as the species recorded in the first column were not collected in those localities.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China—Continued

Name.	Stratigraphic position.			General geographic position.								
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Sin-t'ai-hién.	Near Wu-t'ai-hién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Tschang-hsing-tau Island.
TRILOBITA—Continued.												
Pterocephalus asiaticus		×			C 12							
Pterocephalus busiris			×		C 61				C 54			
Pterocephalus ? liches		×										35*n*
Shantungia spinifera		×			C 6							36*f*
Inouyia abaris		×			C 7 C 9							
Inouyia ? acalle		×			C 12							
Inouyia armata		×						C 75				
Inouyia capax		×									C 70	
Inouyia divi		×		C 24	C 1 C 5							
Inouyia ? inflata		×								C 69		
Inouyia melie		×						C 75			C 70	
Inouyia ? regularis		×								C 73		
Inouyia thisbe		×		C 28								
Inouyia titiana		×			C 7							
Agraulos abrota		×		C 23								
Agraulos dirce		×					C 52					
Agraulos dolon		×			C 7							
Agraulos dryas		×		C 29								
Agraulos nitida		×						C 75				
Agraulos obscura		×								C 69		
Agraulos sorge		×										35*n*
Agraulos uta		×						C 75				
Agraulos vicina		×									C 70	
Pagodia bia			×						C 56			
Pagodia dolon			×			C 41						
Pagodia lotos			×						C 56			
Pagodia macedo			×			C 34						
Lisania agonius		×			C 1 C 2							
Lisania ajax		×			C 12 C 40							
Lisania alala		×		C 22 C 30	C 4	C 46 C 51						
Lisania ? belenus		×		C 19								
Lisania bura		×		C 22								
Lisania cf. bura		×						C 77				
Lisania sp. undt.		×	×	C 30		C 41						
Solenopleura agno		×		C 25		C 51						35*r*
Solenopleura beroe		×	×		C 64							35*n*
Solenopleura chalcon		×										35*r*
Solenopleura intermedia		×				C 51						
Solenopleura pauperata		×									C 71	
Solenopleura sp. undt.		×		C 21								35*n*
Chuangia batia			×		C 11 C 61 C 64	C 44	C 33*a*					
Chuangia fragmenta			×		C 61							
Chuangia nais			×		C 64							
Chuangia nitida			×		C 11							
Menocephalus abderus		×		C 19								
Menocephalus acanthus		×		C 22								
Menocephalus acerius		×		C 18								
Menocephalus acidalia		×		C 30								
Menocephalus acis		×				C 35						
Menocephalus admeta		×		C 22								
Menocephalus agave		×		C 30								
Menocephalus ? depressus			×			C 49			C 56			
Menocephalus ? sp. undt.		×		C 30	C 10							
Levisia adrastia		×		C 30								
Levisia agenor		×		C 25								
Ptychaspis acamus			×			C 45						

NOTE.—The columns "Near Chön-p'ing-hién," "Near Ting-hiang-hién," and "Near Kao-kia-p'u" are omitted in this page, as the species recorded in the first column were not collected in those localities.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China—Continued

Name.	Stratigraphic position.			General geographic position.										
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Sin-t'ai-hién.	Near Wu-t'ai-hién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Near Ting-hiang-hién.	Near Kao-kia-p'u.	Tschang-hsing-tau Island.
TRILOBITA—Continued.														
Ptychaspis baubo			×		C 61, C 64									
Ptychaspis bella			×							C 74				
Ptychaspis brizo			×			C 38								
Ptychaspis vacus			×		C 64									
Ptychaspis cadmus			×			C 41								
Ptychaspis calchas			×			C 41								
Ptychaspis callisto			×		C 64									
Ptychaspis calyce			×		C 54	C 42								
Ptychaspis campe			×			C 42								
Ptychaspis ceto			×		C 64	C 34, C 38, C 45			C 54, C 56					
Ptychaspis sp. undt.			×		C 64	C 47, C 50	C 33		C 54, C 67					
Anomocare alcinoe		×											C 57	
Anomocare convexa *		×												
Anomocare daulis		×		C 19, C 26?										
Anomocare ephori		×												35n, 35r
Anomocare flava		×								C 72				
Anomocare latelimbatum		×			C 2		C 52							35n
Anomocare lisani		×												35q
Anomocare megalurus		×										C 37		35n
Anomocare minus		×			C 9									35n, 36e, 36h
Anomocare minus var.		×												35n, 36e
Anomocare ? nereis		×								C 69, C 72				
Anomocare subquadratum		×			C 7									35n
Anomocare sp. undt.		×						C 77						
Anomocare various sp. undt.		×	×	C 30	C 5, C 8, C 64	C 46								
Anomocarella albion		×			C 1, C 2, C 4								C 57	
Anomocarella baucis			×			C 36								
Anomocarella bergioni			×				C 33a							
Anomocarella bigsbyi		×									C 71			
Anomocarella biston		×			C 2									
Anomocarella butes		×			C 5		C 52							
Anomocarella chinensis		×			C 1, C 2, C 4, C 62								C 57	35n, 35r, 36g
Anomocarella comus		×									C 71			
Anomocarella hermias		×												35n
Anomocarella irma		×						C 77						
Anomocarella macar		×												35n
Anomocarella smithi *		×												
Anomocarella speciosa †		×												
Anomocarella subrugosa		×			C 7									
Anomocarella tatian		×		C 33										
Anomocarella temenus		×		C 22	C 10									35n, 35r
Anomocarella tenes		×		C 28										
Anomocarella thraso ‡		×			C 7									
Anomocarella toxeus		×		C 28										
Anomocarella trogus		×		C 25										
Anomocarella tutia		×		C 19	C 12									

* Occurs in 90 x, Middle Cambrian, Coosa Valley, Alabama, and is introduced for comparison.

† Occurs at Wang-tschuang, Shan-tung, China.

‡ On rock with *Inouyia titiana*.

NOTE.—The column "Near Chön-p'ing-hién" is omitted in this page, as the species recorded in the first column were not collected in that locality.

General Stratigraphic and Geographic Position of the Cambrian Faunas of China —Continued

Name.	Stratigraphic position.			General geographic position.								
	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.	Near Ch'ang-hia.	Near Yen-chuang.	Near Ch'au-mi-tién.	Near Tsi-nan.	Near Fang-lan-chön.	Near Tung-yü.	Near Chön-p'ing-hién.	Near Kao-kia-p'u.	Tschang-hsing-tau Island.
TRILOBITA—Continued.												
Anomocarella undata	....	×	....	....	......	......	......	....	C 71	......	....	....
Coosia ? bianos	....	......	×	....	C 64	......	......	....	....	......	....	....
Coosia carme	....	......	×	....	......	C 38	......	....	....	......	....	....
Coosia ? daunus	....	×	....	....	C 2	......	......	....	....	......	....	....
Coosia decelus	....	×	....	....	C 9	......	......	....	....	......	....	....
Coosia robusta *	....	×	....	....	......	......	......	....	....	......	....	....
Coosia superba †	....	×	....	....	......	......	......	....	....	......	....	....
Dolichometopus alceste	....	×	....	....	C 1, C 4	......	......	....	....	......	....	....
Dolichometopus deois	....	×	....	C 19	C 1, C 2, C 4	....	......	....	....	......	C 57	35o, 35p, 35r
Dolichometopus derceto	....	×	....	....	C 1, C 2	......	......	....	....	......	....	....
Dolichometopus dirce	....	×	....	C 24	......	......	......	....	....	......	....	....
Dolichometopus hyrie	....	×	....	....	......	......	......	C 69	....	......	....	....
Dolichometopus ? sp.	....	×	....	....	C 5	......	......	....	....	......	....	....
Hysterolenus ? sp. undt.	....	......	×	....	......	C 38	C 56	....	....	......	....	....
Bathyuriscus manchuriensis	....	×	....	....	......	......	......	....	....	......	....	35o, 36g, 36h
Asaphiscus iddingsi	....	×	....	....	......	......	......	....	....	......	....	35r, 36e
Tsinania canens	....	......	×	....	......	C 34, C 38, C 41, C 42	C 54	....	....	......	....	....
Tsinania ceres	....	......	×	....	......	C 38	......	....	....	......	....	....
Tsinania dictys	....	......	×	....	......	......	C 56	....	....	......	....	....
OSTRACODA.												
Aluta bergeroni	....	×	....	....	......	......	......	....	....	C 32	....	....
Aluta enyo	....	×	....	....	......	......	......	....	....	C 32	....	....
Aluta eris	....	×	....	....	......	......	......	....	....	C 32	....	....
Aluta fragilis	....	×	....	....	......	......	......	....	....	C 32	....	....
Aluta sterope	....	×	....	....	......	......	......	....	....	C 32	....	....
Aluta woodi	....	×	....	....	......	......	......	....	....	C 32	....	....

* Occurs in 107, Middle Cambrian, Alabama, and is introduced for comparison.
† Occurs in 91, Middle Cambrian, Alabama, and is introduced for comparison.

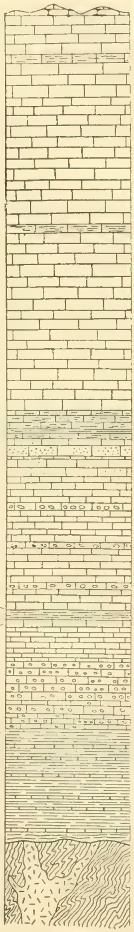
NOTE.—The columns "Near Sin-t'ai-hién," "Near Wu-t'ai-hién," and "Near Ting-hiang-hién" are omitted in this page, as the species recorded in the first column were not collected in those localities.

RELATIONS OF THE FAUNA TO TYPICAL STRATIGRAPHIC SECTION

In order to avoid the repetition of the lists of species from the various localities, a list of localities with the species occurring in each is given (pp. 17-34). In the following stratigraphic sections the numbers designating the localities will be inserted so that the student may, if he desires to learn just which species occur in a given locality and position in the section, refer to the list under the locality number. In some instances it is not practicable from the known stratigraphic and paleontologic data to assign the exact horizon. In such cases an interrogation mark is placed before the locality number.

Sections in Shan-tung

The following sections are copied from Vol. 1, part 1, Research in China,[1] and in addition the locality numbers of the fossils are inserted.



				Locality numbers.	Feet.	Meters.	Present land surface.
Sinian.	Ordovician.	Tsi-nan dolomite.	€Ot		1,800	550	Dolomitic limestone, dark gray and liver-brown colors.
Sinian.	Ordovician.	Tsi-nan dolomite.	€Ot		300	90	Shaly gray limestones and shales, buff crystalline dolomite, and thin white limestone.
Sinian.	Cambrian.	Ch'au-mi-tién limestone.	€cm	36, 45, 47, 50, 67, 68. 34, 38, 41, 42, 49.	600	180	Blue-gray limestone, conglomeritic at various horizons.
Sinian.	Cambrian.	Ku-shan shale.	€k		50	15	Green shale and slabby limestone
Sinian.	Cambrian.	Ch'ang-hia limestone.	€ch	22, 24, 25, 26 19. 18, 21, 35, 46. 30, 51. 29, 48. 23. 28.	500	150	Gray limestone mottled with ocher. Dark gray oolitic limestone. Olive-gray oolitic limetone.
Sinian.	Cambrian.	Man-t'o shales.	€m	17. 20. 31. 15, 16, 27.	500	150	Brown shale with thin gray limestones. Buff and gray shales with gray and buff earthy limestone and black slabby limestone.
T'ai-shan.	Archean.	T'ai-shan complex.	ARt				Schists and gneisses with intruded granite, syenite, etc.
				Totals	3,750	1,135	

Fig. 1.—Section of the Sinian System in the Ch'ang-hia District, Shan-tung

[1] Willis and Blackwelder, 1907. Pub. No. 54, Carnegie Institution of Washington, Vol. 1.

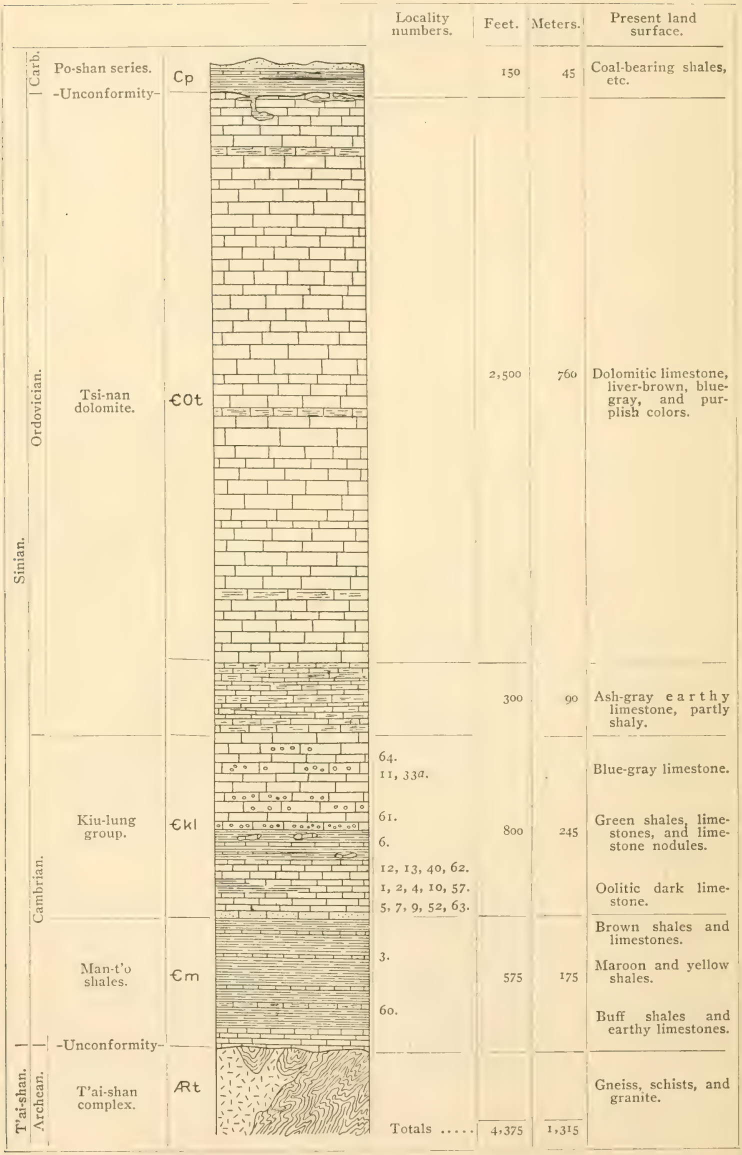
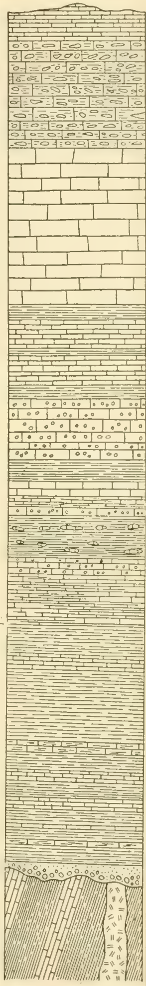


FIG. 2.—SECTION OF THE SINIAN SYSTEM IN THE SIN-T'AI DISTRICT, SHAN-TUNG



			Locality numbers.	Feet.	Meters.	Present land surface.
Cambro-Ordovician.	Ki-chóu limestones.	€Ok	74.	20+	6+	Dense blue limestone.
			73.	75	23	Ocherous, gray, dense, conglomeritic limestone.
			77.	110	33	Massive ocherous gray limestone.
			37, 72.	65	20	Brown and gray shales and thin-bedded limestone.
			71.	45	14	Massive gray oolitic limestone.
				15	4.5	Gray shales.
				9	3	Gray crystalline limestone.
				8	2.5	Gray calcareous shale.
				5	1.5	Oolitic limestone.
			69.	30	9	Gray and buff shales with limestone nodules.
			70.	12	3.5	Hard brown-gray oolitic limestone.
			75.	35	10.5	Slabby buff limestone, dense and hard.
	Man-t'o shales.	€m		80	25	Red shales with thin reddish limestones.
				40	12.5	Red shale and argillaceous limestone, with thin yellow limestones
				30	9	Red shale and thin limestone.
				4	1.3	Argillaceous yellow limestone.
				12	3.5	Red calcareous shale.
				3 to 15	1 to 5	Red sandstone and conglomerate.
Algonkian.	Hu-t'o system.	Ah		610+	180+	Purple argillites; siliceous limestones and dikes of greenstone.

FIG. 3.—PARTIAL SECTION OF THE SINIAN SYSTEM SOUTH OF TUNG-YÜ, SHAN-SI

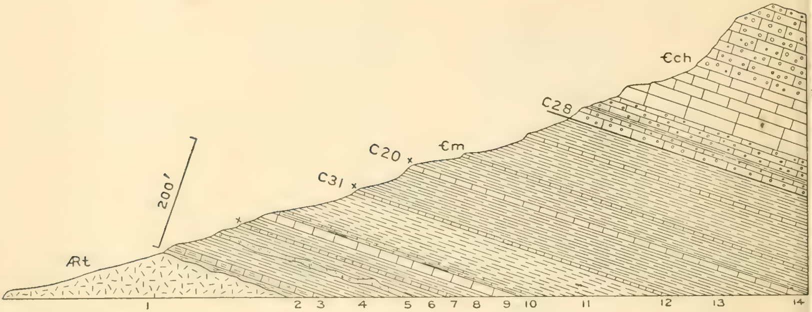


FIG. 4 (Blackwelder).—Ch'ang-hia, Shan-tung. Section of Cambrian strata in the north side of Man-t'o butte. 1 = red granite; 2 = soft yellow shales; 3 = buff earthy limestone; 4 = gray and buff calcareous shales; 5 = syenite-porphyry sheet; 6 = greenish shale; 7 = earthy limestone; 8 = maroon shale; 9 = buff earthy limestone; 10 = white calcareous shale; 11 = red shale; 12 = olive-gray limestone; 13 = dark shales; 14 = gray limestone; 15 = maroon shale; 16 = gray limestone; 17 = brown and gray shales; 18 = gray limestone; 19 = brown shale; 20 = thin-bedded, dark oolite and greenish shale; 21 = gray limestone with black oolitic bodies. This scale of thickness is indicated in feet.

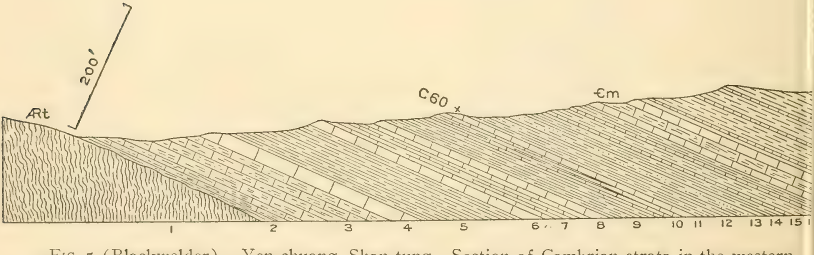


FIG. 5 (Blackwelder).—Yen-chuang, Shan-tung. Section of Cambrian strata in the western part of the Kiu-lung-shan. 1 = gray gneiss; 2 = bright green shale; 3 = gray earthy limestone; 4 = dense blue-black limestone; 5 = brown and yellow shale; 6 = blue-gray limestone; 7 = shaly gray limestone: 8 = dense blue-black limestone; 9 = yellow shale; 10 = gray limestone and shale; 11 = slaty black limestone; 12 = chocolate slate; 13 = brown shaly sandstone; 14 = yellow shale; 15 = buff earthy limestone; 16 = red shale. (Section continued in fig. 6.)

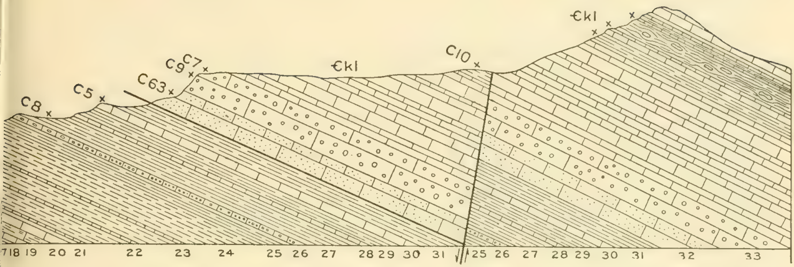


FIG. 6.—17 = black limestone; 18 = yellow shale; 19 = purple-gray limestone; 20 = gray limestone; 21 = yellow shale and thin limestone; 22 = red shale and thin limestone; 23 = green-gray limestone; 24 = red and yellow shale; 25 = maroon shale; 26 = greenish conglomeritic limestone; 27 = brown shale; 28 = buff earthy limestone; 29 = olive-green shale; 30 = cross-bedded green-gray limestone; 31 = olive shale; 32 = gray sandy limestone; 33 = hard dark oolite; 34 = light and dark gray limestone; 35 = green shale; 36 = dense gray limestone; 37 = green nodular shale and thin limestone; 38 = massive dark limestone. The scale of thickness of figures 5 and 6 is indicated in feet.

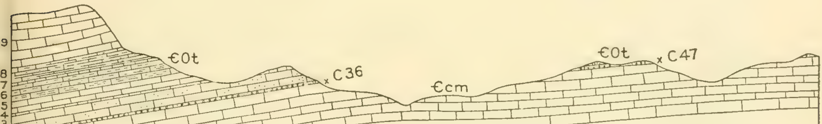


FIG. 7 (Blackwelder).—Ch'au-mi-tién, Shan-tung. Section of Upper Cambrian and Lower Ordovician strata in the ridge east of the village. 1 = dense blue-gray limestone; 2 = conglomeritic limestone; 3 = sandy yellow dolomite; 4 = white earthy limestone; 5 = buff crystalline dolomite; 6 = shaly gray limestone; 7 = blue-gray limestone; 8 = slabby yellow limestone; 9 = dense brown limestone.

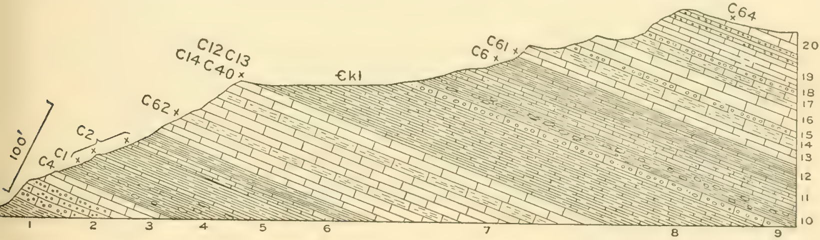


FIG. 8 (Blackwelder).—Yen-chuang, Shan-tung. Section of Kiu-lung formation in Kiu-lung-shan. 1 = Man-t'o shales; 2 = dark limestone, partly oolitic; 3 = dense gray limestone; 4 = nodular green shale; 5 = dense gray limestone; 6 = gray shale and slabby limestone; 7 = thin-bedded dense gray limestone; 8 = green calcareous shale; 9 = conglomeritic limestone; 10 = nodular green shale; 11 = slabby blue limestone; 12 = shaly limestone and gray shale; 13 = black limestone; 14 = slaty gray limestone; 15 = conglomeritic limestone; 16 = massive gray limestone; 17 = thin-bedded gray limestone; 18 = red conglomeritic limestone; 19 = dark gray limestone, locally conglomeritic; 20 = massive gray limestone.

The assembling of the various geologic sections for the purpose of correlating them and their contained faunas led to the construction of fig. 9, on page 57, in which each section is assigned its approximate position in relation to the other sections and to a theoretically entire section. The various finds of fossils are given the same locality number as in the sections already described and in the list of localities [pp. 17-34].

Section in Manchuria

The following section was measured by Prof. Joseph P. Iddings on the island of Tschang-hsing-tau, Province of Liau-tung, Manchuria. Read from the top downward:

	Feet
Massive dark gray limestone, in places mottled	200
About 500 feet of thinly bedded nodular limestone and shale. Hard and upturned, with occasional signs of trilobites. Locality 36*f* is in the upper portion of this belt	500
About 300 feet of massive limestone, in places oolitic. Locality 36*j*	300
20 feet of shale followed by thinly bedded limestone. Locality 35*q*	20
Huge concretions resembling corals—4 to 6 feet in diameter in thin buff shale. Locality 36*i*	4-5
More abundant shale, less limestone and green, dark gray, and brownish shales with thin layers of nodular limestone. Locality 35*p*	200
The exact connection is not shown of localities 35*n*, 35*r*, 36*c*, and 36*e*: green and purple shales	
White quartzitic sandstone in low cliffs, only narrow belt exposed	
Total	1,225

Notes on Horizon of Collections

Localities 35*n*, 35*r*, 36*c*, 36*d*, and 36*e* are very nearly the same horizon, being located above a low bluff, 10 feet high, with nearly horizontal strata in places slightly folded and faulted. These are the lowest beds and not far above the basal.

Locality 35*p* is about 80 feet higher up in the shales and limestone.

Locality 36*h* is about 50 feet higher than No. 35*p*.

Localities 36*g* and 35*o* are back from the bluff on drainage cuts in shale about the horizon of No. 36*h*, I judge.

Locality 35*q* is about 70 feet higher up than No. 36*h*.

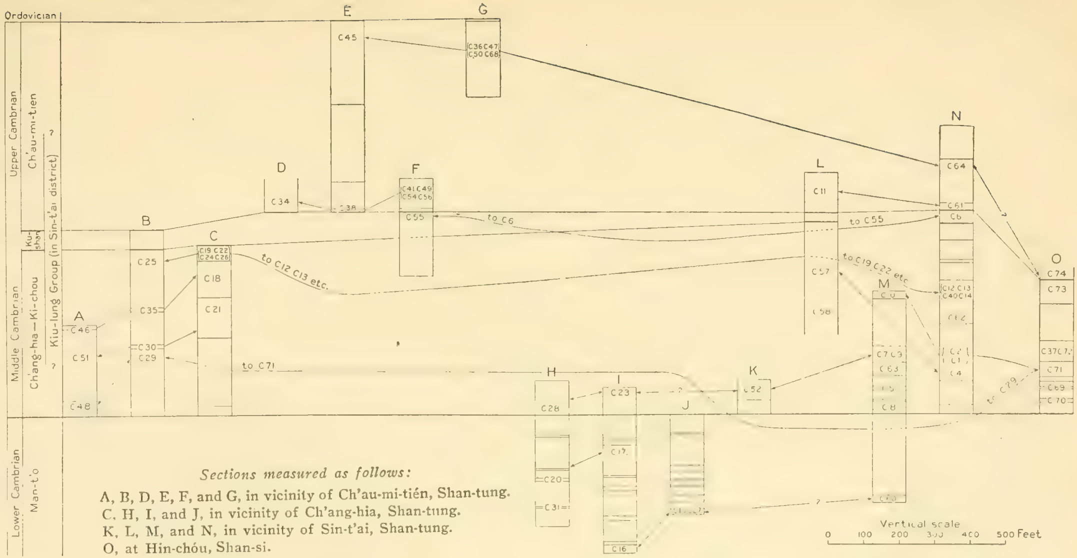
Locality 36*f* is the highest from which fossils were collected and is possibly 800 feet higher up than No. 36*c*.

DISCUSSION OF THE CAMBRIAN FAUNA OF CHINA

The discussion of the fauna might be extended to include a detailed comparison of each species with forms resembling it from Cambrian formations in other parts of the world, but the illustra-

VIEW SHOWING MASSIVE CHARACTER OF CAMBRO-ORDOVICIAN LIMESTONE, IN BROAD SYNCLINE EAST OF YAU-T'ÓU COAL FIELD, PROVINCE OF SHAN-SI.

View also illustrates abrupt walls of recent canyons where they are cut in heavy limestone. On the T'ai shan-ho 4 miles (6.4 km.) southwest of Shi-pan-k'óu, in the district of Wu-t'ai-hién, Province of Shan-si. (After Willis, Research in China, Pub. No. 54, Carnegie Institution of Washington. Vol. 1, Pt. 1, 1907, Pl. 20, p. 148.)



Sections measured as follows:

A, B, D, E, F, and G, in vicinity of Ch'au-mi-tién, Shan-tung.
C, H, I, and J, in vicinity of Ch'ang-hia, Shan-tung.
K, L, M, and N, in vicinity of Sin-t'ai, Shan-tung.
O, at Hin-chóu, Shan-si.

FIG. 9.—Correlation Table of the Fossiliferous Sections measured by Professors Willis and Blackwelder, showing Stratigraphic Positions of the Localities.

tions on the plates show the characters of the species so well that I will leave to each investigator the decision as to whether the species of the fauna he may be considering are similar to those of the Chinese Cambrian. In the following notes only general statements and conclusions are given.

Algæ.—So far as known no true Algæ have been found, but fillings of mud cracks and annelid trails occur resembling stems of Algæ; their true character may be determined by comparison with similar recent phenomena.

Foraminifera.—The almost total absence of Foraminifera is probably due to oversight connected with hurried collecting and to the absence of favorable conditions for the presence and preservation of specimens. The one species *Globigerina ? mantoensis* [plate 1,[1] fig. 1] is all that has been detected in the relatively large collections.

Porifera.—Only a few spicules of *Protospongia* are known. These indicate that when a favorable locality is discovered a fine representation of the sponges will be found.

Anthozoa.—One genus with one species of *Coscinocyathus* suggests the great development of the Archæocyathinæ in the Atlantic Basin fauna as found in the islands of Sardinia and Newfoundland, and the Pacific Basin fauna in the Cordilleran area of Nevada in western America. In Asia the type is known from Siberia as described by Eduard von Toll.[2]

Annelida.—A few trails are all the traces that have been found of the annelids. One of these is illustrated by plate 1, figure 5.

Brachiopoda.—Among the brachiopods none of the genera is peculiar to the Chinese Cambrian. All belong to genera found in the Middle Cambrian of western North America and northwestern Europe. The genus *Micromitra* is well developed and I have inserted on plate 1, figure 13, a photographic reproduction of a specimen from the Middle Cambrian of British Columbia, that has the pedicle and surface spines finely preserved.

Gastropoda.—The patelloid forms are represented by two genera, *Scenella* and *Matherella*, and three species, two from the Middle Cambrian (C 18, C 70) and one from the Upper Cambrian (C 56); the cone-shaped forms by three species of the genus *Helcionella*, one of which, *Helcionella rugosa chinensis* [plate 5, fig. 8], has a

[1] The plate numbers refer to plates accompanying the large memoir on "The Cambrian Faunas of China," Pub. No. 54, Vol. 3, Carnegie Institution of Washington, 1913.

[2] Mém. de l'Acad. imp. des sci. de St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, Beiträge zur Kentniss des sibirischen Cambrium.

dissepiment toward the apex, a feature also shown by both *H. ? ? simplex* [plate 5, fig. 11] and *H. ? clurius* [plate 5, fig. 7]. The coiled gastropods are of unusual interest, as three forms, *Matherella ?* sp. undt. (C 55) [plate 5, fig. 6], *Pelagiella chronus* (C 1, C 4, C 18) [plate 5, figs. 9, 9*a-b*], and *P. willisi* (C 72) [plate 5, figs. 12, 13] are from the Middle Cambrian.

Pteropoda.—The species of the genera *Hyolithes* and *Orthotheca* are of the usual Cambrian type. I have introduced on plate 6, figure 8, a reproduction from a photograph of a *Hyolithes* (*H. carinatus* Matthew) that shows the operculum in position, also the support of the fin-like arms so characteristic of recent pteropods.

Cephalopoda.—One genus and one species from a horizon 480 feet (146 m.) below the summit assigned to the Upper Cambrian are all that are known of this class. The species *Cyrtoceras cambria* (C 56) [plate 6, figs. 4, 4*a-c*][1] is a typical example of the family Cyrtoceridæ and from its presence we are compelled to consider that there was a large and varied cephalopod fauna in the area, from which it migrated into the Sinian sea. It is a reminder of our want of data on the fauna of the Upper Cambrian and of the great harvest to be gathered by the future field-worker and student of the stratigraphic geology of Asia.

In the Ozark region of Missouri in North America Ulrich has found both the Cephalopoda and Gastropoda extensively developed at a horizon not much above that of *Cyrtoceras cambria,* if we base the correlation on the character of the trilobites in the two distant localities.

Trilobita.—The exceptional genera of the Trilobita found in China and not known to occur elsewhere are *Stephanocare* [plate 7], *Teinistion* [plate 9], *Blackwelderia* [plate 9], *Damesella* [plate 9], and *Drepanura* [plate 10]. All other genera are represented in western North America and western Europe, and there is a striking resemblance even to specific characters in many of the forms. The most noticeable omissions of American and European genera from the Chinese fauna are *Paradoxides* of the Atlantic Basin fauna and *Olenoides, Dikelocephalus,* and *Neolenus* of the North American fauna. The closely related genus *Dorypyge* (to *Olenoides*) is found abundantly in China, western United States, and on the island of Bornholm in northwestern Europe.

The genera *Ptychoparia, Conokephalina, Acrocephalites, Inouyia, Agraulos, Lisania, Solenopleura, Anomocare, Anomocarella* and

[1] The plate numbers refer to plates accompanying the large memoir on "The Cambrian Faunas of China."

Coosia are well represented in China, western North America, southwestern United States, and northwestern Europe. *Bathyuriscus* and *Asaphiscus* are essentially Pacific Basin types. They represent the most advanced forms of the Trilobita of Middle Cambrian time and may be compared with *Asaphus* and *Bathyurus* of the Ordovician fauna.

Redlichia is an intermediate form that serves in a limited degree to connect the Mesonacidæ[1] and the Paradoxidæ. Its tapering glabella and elongate eye-lobes recall those of *Nevadia,* and its small pygidium that of *Holmia* and *Callavia*.[2]

Many species of trilobites are represented only by fragments of the cephalon, scattered segments of the thorax, and pygidia that can only be tentatively designated as probably belonging to the same species as an associated cephalon. In some instances the cephala of otherwise distinct genera are so nearly similar that in the absence of the thorax and pygidium they would be referred to one genus. This is particularly the case among the genera of the Ptychoparidæ.

THE LARGER FAUNAL HORIZONS

The geographic distribution and characters of the Lower, Middle, and Upper Cambrian divisions of the eastern and southern Asiatic Cambrian faunas vary to such an extent as to make it desirable to consider them separately. It seems from our present information that the Cambrian sea first transgressed the southern and southeastern sections of the continent in late Lower Cambrian time and that certain changes occurred in its distribution at intervals during the remainder of Cambrian time. The data, however, are still too limited to give more than very approximate limits to the distribution of the faunas. Extended areal mapping of the distribution of the geologic formations and faunas will be necessary before paleogeographic maps of eastern Asia can be made that are more than broad outlines to be changed and filled in very much as the geographic map of Africa was modified from time to time during the last half of the nineteenth century.

Lower Cambrian fauna.—The Lower Cambrian (Man-t'o shale) *Redlichia* fauna of Shan-tung, Shan-si, Yun-nan, and northern India is, so far as known, very distinctive and confined to the Asiatic continent and Australia.

[1] Walcott, C. D. Smithsonian Misc. Coll., Vol. 53, Cambrian Geology and Paleontology, No. 6, 1910, pp. 231-422, pls. 23-44: *Olenellus* and other genera of the Mesonacidæ.

[2] Idem, pl. 44.

The fauna is unknown in Manchuria, although Blackwelder considered that the Yung-ning sandstone of southern Liau-tung was probably of Lower Cambrian age.[1]

In this and the following lists I have combined the local lists, placing after each species the locality number, so that each species may be traced back to its local list and thus found with its immediate associates in the strata.

In Central Shan-tung the Man-t'o sandstones contain a small fauna, as follows:

Billingsella richthofeni (C 3, C 20)
Obolella asiatica (C 17, C 32')
Helcionella rugosa chinensis (C 3)
Hyolithes delia (C 3)
Hyolithes sp. undt. (C 32')
Redlichia chinensis (C 15, C 16, C 27)
Redlichia nobilis (C 3)
Redlichia sp. undt. (C 6)
Ptychoparia aclis (C 17, C 20, C 31)
Ptychoparia granosa (C 17)
Ptychoparia impar (C 17)
Ptychoparia ligea (C 31)
Ptychoparia (*Emmrichella*) *constricta* (C 3)
Ptychoparia (*Emmrichella*) *mantoensis* (C 20, C 31)

Of the above, *Obolella asiatica, Helcionella rugosa chinensis,* and *Redlichia chinensis* may be considered as characteristically Lower Cambrian. I do not know of the occurrence of the genus *Obolella* above the Lower Cambrian[2] and *Helcionella rugosa* belongs to the same fauna. *Redlichia chinensis* and *R. nobilis* have been referred to as descendent from *Olenellus*,[3] but I would now cite *Callavia* in place of *Olenellus,* as the latter genus appears to have left no descendants. It should also be noted that the very ancient form *Nevadia* has a tapering glabella and long eye-lobes,[4] which leads me to consider *Redlichia* as an example of reversion to a more primitive type in the form of the glabella. The thorax and pygidium of *Redlichia* are more like the same parts in *Wanneria*,[5] except for the median spines of the thoracic segments.

It is to be anticipated that the Man-t'o shale *Redlichia* fauna will be found at other localities in eastern China, but at the present writing the nearest locality is in southern China near Yun-nan, about 1,300 miles (2,100 km.) to the southwest. At this locality *Redlichia chinensis* occurs in a shale and associated with it a new genus of

[1] Blackwelder, Eliot. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, Pt. 1, 1907, Chap. 5, Reconnaissance in southwest Liau-tung, p. 87.

[2] Walcott, C. D. Monogr. U. S. Geol. Survey, Vol. 51, 1912, Cambrian Brachiopoda, p. 588.

[3] Idem, Smithsonian Misc. Coll., Vol. 53, Cambrian Geology and Paleontology, No. 6, 1910, *Olenellus* and other genera of the Mesonacidæ, p. 254.

[4] Idem, pl. 23.

[5] Idem, pl. 30.

trilobites allied to *Agraulos* named *Palæolenus* by Mansuy.[1] The fauna includes:

ANNELIDS:
- *Planolites ?*

BRACHIOPODS:
- *Obolus ? detritus* Mansuy
- *Obolus damesi* Walcott
- *Obolus* cf. *chinensis* Walcott
- *Lingula yunnanensis* Mansuy
- *Acrothele matthewi eryx* Walcott
- *Acrothele orbicularis* Mansuy

OSTRACODS;
- *Bradoria douvilléi* Mansuy
- *Aluta* sp. *?*
- *Nothozoe ?*

TRILOBITES:
- *Redlichia chinensis* Walcott
- *Redlichia nobilis* Walcott
- *Redlichia walcotti* Mansuy
- *Redlichia carinata* Mansuy
- *Redlichia* sp.
- *Palæolenus douvilléi* Mansuy
- *Palæolenus lantenoisi* Mansuy
- *Palæolenus deprati* Mansuy
- *Ptychoparia yunnanensis* Mansuy

An interval of about 1,700 miles (2,700 km.) occurs between the Yun-nan locality of *Redlichia* and its occurrence in northern India in Spiti as the closely allied species *R. noetlingi*.[2]

In western Australia *Redlichia* occurs in the Kimberley district. It was published as *Olenellus ? forresti* [Etheridge, Jr., MSS.] by Arthur H. Foord.[3]

In South Australia a very good specimen of the central portions of the cephalon is mentioned as *Olenellus* sp., by R. Etheridge, Jr.[4]

The distribution of *Redlichia,* of the *R. noetlingi* form, serves to demonstrate that the transgressing Lower Cambrian sea that contained the *Redlichia* fauna was confined to eastern and southeastern China and northern India. The presence of *Redlichia*-like trilobites in southern and western Australia indicates that there was direct connection between the Punjab Lower Cambrian sea of India and the shallow seas about the Australian area. There is no record pointing to a connection between the Punjab-Man-t'o sea and the Lower Cambrian seas of northern Siberia, or western North America.

Middle Cambrian fauna.—The lower portion of the Middle Cambrian section and its contained fauna show that a marked change

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[1] Mém. service géol. l'Indo-Chine, Vol. 1, 1912 (received May 8, 1913), fasc. 2, Étude géologique Paléontologie, pp. 27-30.

[2] Mem. Geol. Surv. India, n. ser., Vol. 1, 1901, p. 2; also Idem, series 15, Vol. 7, No. 1, 1910, p. 7.

[3] Geol. Mag., London, Dec. III, Vol. 7, 1890, p. 199, plate 4, figs. 2, *2a-b*.

[4] Trans. Roy. Soc. South Australia, Vol. 29, 1905, plate 25, fig. 1. (See Tate, idem, Vol. 15, 1892, Cambrian fossils of South Australia, pl. 2, p. 183.)

took place at the close of the Man-t'o shale epoch. Willis concludes that aridity and severe cold were conditions of the climate during Man-t'o shale time; that life was abundant elsewhere and with the changing climate it developed rapidly in the seas following the Man-t'o.[1] Of the rocks of the Kiu-lung group following the Man-t'o, he says:

> *Middle Sinian, Kiu-lung group.*—The Kiu-lung group of Shan-tung is a succession of limestones and shales which immediately follows the Man-t'o formation. Transition beds connect the two. Shale is a common rock in both, but in the Man-t'o it is red, whereas in the Kiu-lung it is green. Limestone is thin-bedded and subordinate in the former, in the latter it is usually massive and predominant. The Man-t'o contains a sparse Middle or Lower Cambrian fauna in its upper portion; the Kiu-lung carries very abundant faunas, which range from Middle Cambrian at the base to Upper Cambrian and possibly to lowest Ordovician at the top.

The known distribution of the limestones and shales and their contained faunas of the Middle Cambrian is outlined by Willis, also the area in which they are supposed to occur.[2] The known distribution from Manchuria on the northeast to central China, and west into northern India,[3] taken with the occurrence of fragments of the fauna in Siberia in the valleys of the Lena, Yenisei, and Angara,[4] indicates something of the extent of the Middle Cambrian sea. The larger area outlined by Willis in which Cambrian rocks are supposed to occur is probably much too small, as later rocks undoubtedly conceal large areas of the Cambrian.

The prevalence of limestones with interbedded calcareous and argillaceous shales indicates relatively shallow seas and favorable environment for the life of the sea. This inference is supported by the number of genera and species already found in the hurried collecting necessitated by the conditions of exploration met with by the Willis and Iddings parties.

In the Ch'ang-hia District the Middle Cambrian is represented in the Ch'ang-hia limestone, in the Sin-t'ai district by the lower portion of the Kiu-lung limestone, and in Shan-si by the lower 400 feet (118 m.) of the Ki-chóu limestone.

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[1] Willis, Bailey. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, p. 40.

[2] Idem, pl. 4.

[3] Reed, F. R. C. Mem. Geol. Survey India, Palæontologia Indica, ser. 15, Vol. 7, 1910, No. 1, The Cambrian fossils of Spiti, p. 66.

[4] Toll, E. von. Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, Beiträge zur Kentniss des sibirischen Cambrium, pp. 1-57, pls. 1-8, and 9 text figs.

The lower portion of the Kiu-lung group lower limestone contains the following fauna:

Globigerina ? mantoensis (C 5)
Coscinocyathus elvira (C 75)
Micromitra (*Paterina*) *labradorica orientalis* (C 9)
Micromitra (*Iphidella*) *pannula ophirensis* (C 5)
Obolus damesi (C 7)
Obolus obscurus (C 63, C 75)
Lingulella (*Lingulepis*) *eros* (C 7)
Eoorthis agreste (C 28)
Eoorthis kichouensis (C 75)
Acrotreta pacifica (C 5)
Acrothele rara (C 23)
Orthotheca daulis (C 23)
Scenella ? dilatatus (C 70)
Helcionella ? ? simplex (C 70)
Redlichia finalis (C 58)
Ptychoparia impar var. (C 8)
Ptychoparia lilia (C 75)
Ptychoparia tolus (C 52)
Ptychoparia sp. (C 58)
Ptychoparia (*Emmrichella*) *eriopia* (C 23)
Ptychoparia (*Emmrichella*) *theano* (C 23)
Conokephalina maia (C 70)
Conokephalina sp. (C 70)
Inouyia abaris (C 7, C 9)
Inouyia armata (C 75)
Inouyia capax (C 70)
Inouyia divi (C 5)
Inouyia melie (C 70, C 75)
Inouyia thisbe (C 28)
Inouyia titiana (C 7)
Agraulos abrota (C 23)
Agraulos dirce (C 52)
Agraulos dolon (C 7)
Agraulos nitida (C 75)
Agraulos uta (C 75)
Agraulos vicina (C 70)
Anomocare latelimbatum (C 52)
Anomocare minus (C 9)
Anomocare sp. (C 5)
Anomocare sp. undt. (C 8)
Anomocarella butes (C 5, C 52)
Anomocarella subrugosa (C 7)
Anomocarella tatian (C 23)
Anomocarella tenes (C 28)
Anomocarella thraso (C 7)
Anomocarella toxeus (C 28)
Coosia decelus (C 9)
Dolichometopus ? sp. (C 5)
Bathyuriscus ? sp. (C 28)

Of the above fauna only three species pass into the strata above. One is *Obolus damesi,* which occurs a little higher in the limestone beneath the horizon of the Ku-shan shale, and it has a possible representative in the upper part of the Upper Cambrian. *Inouyia melie* Walcott and *I. divi* Walcott are found in the strata a little higher in the section.

The next succeeding faunal zone contains:

Protospongia chloris (C 4)
Acrothele matthewi eryx (C 4)
Acrothele rara (C 57)
Acrocreta pacifica (C 4)
Pelagiella chronus (C 4)
Hyolithes cybele (C 4)
Hyolithes ? (operculum) (C 4)
Orthotheca delphus (C 4, C 57)
Agnostus chinensis (C 4, C 57)
Agnostus kushanensis (C 57)
Dorypyge richthofeni (C 57)
Conokephalina vesta (C 69)
Inouyia inflata (C 69)
Agraulos obscura (C 69)
Lisania alala (C 4)
Anomocare alcinoe (C 57)
Anomocare nereis (C 69)
Anomocarella albion (C 4, C 57)
Anomocarella chinensis (C 4, C 57)
Dolichometopus alceste (C 4)
Dolichometopus deois (C 4, C 57)
Dolichometopus hyrie (C 69)

This fauna is at the base of the rich *Dorypyge richthofeni* fauna and several of its species continue up into the next grouping of genera and species, which is one of the most important of the sub-faunas of the Middle Cambrian of China. It includes, in the Sin-t'ai district of Shan-tung:

Protospongia chloris (C 1, C 2)
Obolus damesi (C 10)
Obolus minimus (C 1)
Obolus shansiensis ? (C 71)
Obolus (*Westonia*) *blackwelderi* (C 1, C 2)
Yorkia ? orientalis (C 71)
Acrotreta pacifica (C 1, C 2)
Acrotreta shantungensis (C 71) (? C 1)
Eoorthis sp. undt. (C 71)
Pelagiella chronus (C 1)
Hyolithes cybele (C 1, C 2)
Orthotheca cyrene dryas (C 2)
Orthotheca glabra (C 71)
Agnostus chinensis (C 1, C 2, C 71)
Dorypyge bispinosa (C 2)
Dorypyge richthofeni (C 1, C 29)
Dorypyge richthofeni lævis (C 71)
Agraulos dryas (C 29)
Inouyia divi (C 1)
Lisania agonius (C 1, C 2)
Solenopleura pauperata (C 71)
Menocephalus sp. undt. (C 10)
Anomocare latelimbatum (C 2)
Anomocarella albion (C 1, C 2)
Anomocarella bigsbyi (C 71)
Anomocarella biston (C 2)
Anomocarella chinensis (C 1, C 2)
Anomocarella comus (C 71)
Anomocarella temenus (C 10)
Anomocarella undata (C 71)
Coosia ? daunas (C 2)
Ptychoparia sp. undt. (C 48)
Crepicephalus damia (C 71)
Crepicephalus magnus (C 48)
Lonchocephalus tellus (C 2)
Dolichometopus alceste (C 1)
Dolichometopus deois (C 1, C 2)
Dolichometopus derceto (C 1, C 2)

In the Ch'ang-hia district, at a supposed slightly higher horizon, the following genera and species occur:

Obolus chinensis (C 62)
Obolus shansiensis (C 37)
Lingulella (*Lingulepis ?*) sp. undt. (C 72)
Acrotreta lisania (C 22)
Acrotreta cf. *pacifica* (C 24)
Acrotreta shantungensis (C 37, C 62)
Eoorthis sp. undt. (C 26)
Pelagiella willisi (C 72)
Hyolithes cybele (C 22, C 62)
Orthotheca glabra (C 72)
Agnostus sp. undt. (C 24)
Dorypyge richthofeni (C 19, C 24)
Dorypyge richthofeni lævis (C 72)
Damesella brevicaudata (C 19)
Conokephalina sp. undt. (C 72)
Crepicephalus damia (C 26)
Crepicephalus cf. *magnus* (C 25)
Inouyia divi (C 24)
Lisania alala (C 22)
Lisania belenus (C 19)
Lisania bura (C 22)
Solenopleura agno (C 25)
Menocephalus abderus (C 19)
Menocephalus acanthus (C 22)
Menocephalus admeta (C 22)
Levisia agenor (C 25)
Anomocare ? daulis (C 19, C 26)
Anomocare flava (C 72)
Anomocare megalurus (C 37)
Anomocare ? nereis (C 72)
Anomocare sp. (C 25)
Anomocarella chinensis (C 62)
Anomocarella temenus (C 22)
Anomocarella trogus (C 25)
Anomocarella tutia (C 19)
Dolichometopus deois (C 19)
Dolichometopus dirce (C 24)

Above this horizon the fauna again changes. The trilobitic genera *Dorypyge, Dolichometopus,* and *Solenopleura* drop out and the genera *Damesella, Blackwelderia,* and *Teinistion* foreshadow the rich and in many respects unique fauna of the Ku-shan shale.

This fauna in the upper horizon of the Ch'ang-hia limestone in Shan-tung contains the following:

Acrotreta pacifica (C 12)
Teinistion alcon (C 12)
Blackwelderia alastor (C 12)
Blackwelderia cilix (C 73)
Damesella bellagranulata (C 13)
Damesella blackwelderi (C 12, C 13, C 14, C 40)
Pterocephalus asiaticus (C 12)
Inouyia acalle (C 12)
Inouyia ? regularis (C 73)
Lisania ajax (C 12, C 40)
Anomocarella tutia (C 12)

In the Ku-shan shaly beds, just above the beds containing the preceding, the following occur:

Obolus (*Westonia*) *blackwelderi* (C 6)
Dicellomus parvus (C 6)
Acrothele ? minuta (C 6)
Straparollina sp. undt. (C 55)
Agnostus douvilléi (C 6, C 55)
Redlichia sp. undt. (C 6)
Stephanocare ? monkei (C 6)
Stephanocare richthofeni (C 6, C 55)
Stephanocare sinensis (C 6)
Stephanocare ? sp. undt. (C 6)
Blackwelderia cilix (C 55)
Blackwelderia sinensis (C 6)
Drepanura ketteleri (C 6, C 55)
Drepanura ketteleri (C 6, C 55)
Ptychoparia (*Emmrichella*) *bromus* (C 6)
Liostracina krausei (C 6)
Shantungia spinifera (C 6)

This assemblage of genera and species forms a varied and unique fauna, which has little in common with the faunas above and below it in the strata. It is a local phase of the Cambrian fauna corresponding somewhat to one of the subdivisions of the Middle Cambrian fauna of western North America as represented by the fauna of the Stephen formation of British Columbia.[1] In each there are trilobites with large pygidia. *Damesella* and *Neolenus,* respectively, are typical examples, and there are several genera not found at other horizons or in other countries.

The Middle Cambrian fauna of China, like that of western North America, is marked by the absence of the genus *Paradoxides.* Fortunately there are other genera that serve to connect the *Paradoxides* fauna of the Atlantic Province with the *Dorypyge* fauna of the Pacific Province. *Dorypyge* is associated with *Paradoxides, Solenopleura, Anomocare,* etc., in northwestern Europe.[2] In China, *Dory-*

[1] Walcott, C. D. The Canadian Alpine Journal, Vol. 1, No. 2, 1908, Mount Stephen rocks and fossils, pp. 243-244, pls. 1-4.

[2] Grönwall, K. A. Danmarks geol. Unders., Række 2, No. 13, 1902, Bornholms Paradoxideslag og deres fauna, pls. 3, 4.

pyge [see Locality 35*r*, p. 33] is found with *Solenopleura, Anomocare, Dolichometopus,* and other genera associated with *Paradoxides* in the Atlantic Province. The order of stratigraphic succession of the *Dorypyge* fauna is essentially the same in the two provinces.

The Middle Cambrian fauna, like that of western North America, is much larger and more abundant than that of the Upper Cambrian. This was due in a considerable degree to the usually favorable conditions existing on account of the great variety of habitat afforded by the seas of the period. The advancing and deepening Middle Cambrian sea forced the local faunas to change their habitat from time to time and they had either to adjust themselves to the new conditions and habitat or to perish. Local isolation for long periods led to the development of new forms, and these, when the barriers were removed, contested and competed for their position and existence with other faunas until, by a process of elimination of those least fit to survive, the development was hastened of a large and varied fauna. By the close of the Middle Cambrian more stable conditions prevailed and the era of rapid evolution was checked until, under the impulse of new conditions of environment and accumulated tendency to change following the close of the Cambrian, a great evolution of new forms of life began.

Upper Cambrian fauna.—The geographic distribution of the formations containing this fauna is the same as for the Middle Cambrian, so far as now known. In the Sin-t'ai district the upper shale (Ku-shan?) and its fauna serve to form an upper horizon to the Middle Cambrian. The first fauna above the Ku-shan shale occurs in a limestone and, although only 10 feet (3 m.) higher in the section, is entirely distinct from that of the Ku-shan shale. It includes the following:

Billingsella pumpellyi (C 61)	*Chuangia fragmenta* (C 61)
Proampyx burea (C 61)	*Chuangia nitida* (C 11)
Pterocephalus busiris (C 61)	*Ptychaspis baubo* (C 61)
Chuangia batia (C 11, C 33*a*, C 61)	*Anomocarella bergioni* (C 33*a*)

Sixty feet (18 m.) above the Ku-shan shale the fauna includes:

Chuangia batia (C 11, C 33*a*)	*Anomocarella bergioni* (C 33*a*)
Chuangia nitida (C 11)	

In the Ch'ang-hia district, at about 100 to 120 feet (30 to 36 m.) above the base of the formation, the fauna is relatively large and varied. It includes the following:

Obolus matinalis ? (C 54)
Obolus (*Westonia*) sp. undt. (C 56)
Discinopsis sulcatus (C 56)
Eoorthis pagoda (C 54, C 56)
Syntrophia orthia (C 54, C 56)
Scenella sp. undt. (C 56)
Matherella circe (C 56)
Pelagiella pagoda (C 56)
Orthotheca sp. undt. (C 56)
Cyrtoceras cambria (C 56)
Agnostus sp. undt. (C 34)
Conokephalina belus (C 56)
Conokephalina dryope (C 56)
Lisania sp. undt. (C 41)
Pterocephalus busiris (C 54)
Pagodia bia (C 56)
Pagodia dolon (C 41)
Pagodia lotos (C 56)
Pagodia macedo (C 34)
Menocephalus ? depressus (C 49, C 56)
Ptychaspis brizo (C 38)
Ptychaspis cadmus (C 41)
Ptychaspis calchas (C 41)
Ptychaspis calyce (C 42)
Ptychaspis campe (C 42)
Ptychaspis ceto (C 34, C 38, C 54, C 56)
Ptychaspis sp. undt. (C 54)
Coosia carme (C 38)
Hysterolenus sp. (C 38)
Hysterolenus ? (C 56)
Tsinania canens (C 34, C 38, C 54)
Tsinania ceres (C 38)
Tsinania dictys (C 56)
Tsinania sp. undt. (C 54)

The fauna of the upper portion of the Ch'au-mi-tién limestone is best represented from 50 to 75 feet (15 to 23 m.) below the summit of the limestone. It contains a characteristic grouping of genera and species, as follows:

Obolus damesi (C 64)
Eoorthis doris (C 64)
Eoorthis kayseri (C 64, C 68, C 74)
Eoorthis linnarssoni (C 64)
Huenella orientalis (C 64)
Syntrophia orthia (C 64)
Billingsella pumpellyi (C 36)
Pelagiella clytia (C 47)
Hyolithes daphnis (C 64)
Orthotheca cyrene (C 47, C 64)
Coosia ? bianos (C 64)
Anomocare sp. (C 64)
Anomocarella baucis (C 36)
Anomocarella ? sp. undt. (C 68)
Ptychaspis acamus (C 45)
Ptychaspis baubo (C 64)
Ptychaspis bella (C 74)
Ptychaspis cacus (C 64)
Ptychaspis callisto (C 64)
Ptychaspis calyce (C 64)
Ptychaspis ceto (C 45, C 64)
Ptychaspis sp. undt. (C 64)
Ptychaspis sp. (C 47, C 50)
Chuangia batia (C 64)
Chuangia nais (C 64)
Solenopleura beroe (C 64)
Tsinania sp. undt. (45)

The stratigraphic range of the genera of the Upper Cambrian in China is shown by the following table [p. 69]. Of the 27 genera in the table all occur in the Cambrian of North America, with the possible exception of *Chuangia*.

The Upper Cambrian fauna of China is characterized by genera that are well developed in the same fauna in North America. The genus *Ptychaspis* is particularly prominent in species and numbers in the Upper Cambrian both in China and America. *Tsinania* is represented by four species in the central portion of the Ch'au-mi-tién limestone and one at the upper horizon. In America it is found

in the limestones referred to the Upper Cambrian where it has a considerable vertical range[1] and wide geographic distribution.

The absence of a true *Dikelocephalus* is to be noted, as the genus is associated with *Ptychaspis* and *Tsinania* in the Upper Cambrian of the interior portions of the North American continent. It is not certainly known from the western or Cordilleran region.

Class and genus.	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.		
			Base.	Central.	Near summit.
Brachiopoda:					
Obolus	......	×	....	×	×
Discinopsis	......	......	....	×	......
Billingsella	×	......	×	....	×
Eoorthis	......	×	....	×	×
Huenella	......	......	....	....	×
Syntrophia	......	......	....	×	×
Gastropoda:					
Scenella	......	×	....	×	......
Straparollina	......	×	....	×	......
Pelagiella	......	×	....	×	×
Pteropoda:					
Hyolithes	×	×	....	×	×
Orthotheca	......	×	....	×	×
Cephalopoda:					
Cyrtoceras	......	......	....	×	....

Class and genus.	Lower Cambrian.	Middle Cambrian.	Upper Cambrian.		
			Base.	Central.	Near summit.
Trilobita:					
Agnostus	......	×	....	×	......
Conokephalina	......	×	....	×	......
Proampyx	......	......	×	....	......
Pterocephalus	......	×	×	×	......
Pagodia	......	×	....	....	×
Lisania	......	×	....	×	......
Solenopleura	......	×	....	....	×
Chuangia	......	×	×	....	×
Menocephalus	......	×	....	×	......
Ptychaspis	......	×	×	×	×
Anomocare	......	......	....	....	×
Anomocarella	......	×	×	....	×
Coosia	......	×	....	×	......
Hysterolenus	......	......	....	×	......
Tsinania	......	......	....	×	×
Total number	2	18	6	19	15

FAUNAL PROVINCES OF THE CAMBRIAN IN ASIA

Mr. F. R. Cowper Reed[2] has given a summary of the geographic distribution of the Cambrian formation in Asia, and called attention to the probability that Frech's "Pacific Zoögeographical province" would need to be subdivided.[3] I find that while the Cambrian fauna of the Pacific Province of eastern Asia has a strong generic relationship with that of the Rocky Mountain area of western North America, yet in each area there is a group of genera that are not found in the fauna of the other area. On this account it seems best to consider the Rocky Mountain Province[4] as a subprovince distinct from the Middle and Upper Cambrian of the eastern Asian subprovince of the same periods. The Lower Cambrian *Redlichia* fauna of Asia

[1] Walcott, C. D. Smithsonian Misc. Coll., Vol. 53, Cambrian Geology and Paleontology, No. 5, 1908, Cambrian sections of the Cordilleran area, pp. 175, 177, 192, 204, 205.

[2] Reed, F. R. C. Mem. Geol. Survey India, Palæontologia Indica, ser. 15, Vol. 7, 1910, No. 1, The Cambrian fossils of Spiti, pp. 62-70.

[3] Idem, p. 63.

[4] Walcott, C. D. Bull. U. S. Geol. Survey No. 81, 1891, Correlation papers, Cambrian, pp. 313-330, pl. 1.

is so distinct that there is no probability of its having lived in the same province with the Mesonacidæ fauna of North America. The North American Middle Cambrian fauna is distinctive in having the brachiopod genus *Nisusia* Walcott and the trilobitic genera *Karlia* Walcott, *Ogygopsis* Walcott, *Burlingia* Walcott, *Zacanthoides* Walcott, *Oryctocara* Walcott, and *Neolenus* Matthew.

The Chinese Middle Cambrian fauna has in its upper portion a few genera not known from the North American fauna. These include, as described in this memoir, *Damesella, Blackwelderia, Teinistion, Stephanocare, Drepanura, Shantungia,* and *Liostracina.* The fauna containing the genera mentioned, like that of the genera listed above from North America, belongs to a local fauna that did not obtain a distribution outside of the limited area in which it lived. It could not in either case have developed in the communicating seas in which the greater world-wide and typical fauna of the Middle Cambrian lived.

The Upper Cambrian fauna of China, as now known, is essentially the same in its generic aspect with that of western North America. This is discussed in the section on The Larger Faunal Horizons [pp. 60-69].

A comparison of the faunas in the four local areas of the Cambrian in Asia shows the presence of three provinces:

1. Shan-tung Province (including Manchuria and Shan-si subprovince).
2. Pun-jab Province (including Yun-nan area).
3. Siberian Province.

The largest fauna is that of the Shan-tung subprovince. This includes the Cambrian area in Shan-tung and its extension northward in Manchuria. The species common to the Shan-tung and Manchuria areas are:

Protospongia chloris
Micromitra (Iphidella) pannula ophirensis
Obolus chinensis
Obolus damesi
Obolus shansiensis
Acrothele matthewi eryx
Acrotreta pacifica
Acrotreta shantungensis
Hyolithes cybele
Orthotheca cyrene
Orthotheca delphus
Agnostus chinensis
Agnostus douvilléi
Dorypyge richthofeni
Teinistion typicalis
Stephanocare sinensis
Blackwelderia sinensis
Damesella brevicaudata
Drepanura premesnili
Liostracina krausei
Shantungia spinifera
Solenopleura agno
Solenopleura beroe
Anomocare megalurus
Anomocare minus
Anomocare subquadratum
Anomocarella chinensis
Anomocarella temenus
Dolichometopus deois

The Shan-si subprovince[1] has five species of Middle Cambrian fossils and one Upper Cambrian species common to it and to the southern Shan-tung Province area in Shan-tung, as follows:

LOWER CH'ANG-HIA FAUNA.—*Obolus obscurus, Obolus shansiensis, Acrotreta shantungensis, Agnostus chinensis, Crepicephalus damia.*
CH'AU-MI-TIÉN FAUNA.—*Plectorthis kayseri.*

With the Manchurian extensions of the Shan-tung Province the Shan-si fauna has five species in common, as follows:

SHAN-SI AND MANCHURIA.—*Obolus shansiensis, Acrotreta shantungensis, Orthotheca glabra, Agnostus chinensis.*

In southern China, as previously stated [p. 62], there is no record pointing to a connection between the Punjab-Man-t'o sea and the Lower Cambrian seas of northern Siberia, or western North America. The fauna described by M. Mansuy [p. 62] is related to the Man-t'o shale *Redlichia* fauna of Shan-tung.

In Middle Cambrian time, as stated by Reed, the Spiti fauna is more strongly related to that of western North America than to any other Middle Cambrian fauna.[2] So far as China is concerned, the northern Indian fauna is that of another faunal province.

The Cambrian fauna of the Siberian Province includes species that are referred to the Middle Cambrian fauna, and a few that may be tentatively assigned to the Lower Cambrian. Doctor von Toll has identified a number of genera of the Archæocyathinæ[3] that may occur in the upper portion of the Lower Cambrian terrane. The one species of *Coscinocyathus* from China, *C. elvira* Walcott, occurs in the Middle Cambrian, but this is a very small form and may have been a survival in Middle Cambrian time of the large Archæocyathinæ fauna of late Lower Cambrian time. In North America the Archæocyathinæ flourished most abundantly in late Lower Cambrian time[4] on both the eastern and western sides of the continent. Von Toll lists from the *Archæocyathus* limestones of Torgoschino,[5] in

[1] The geographic distribution of the Shan-tung, Manchuria, and Shan-si Cambrian rocks is shown by Willis: Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 2, 1907, Systematic geology, plate 4.

[2] Reed, F. R. C. Mem. Geol. Survey India, Palæontologia Indica, ser. 15, Vol. 7, 1910, No. 1, The Cambrian fossils of Spiti, pp. 64, 65.

[3] Toll, E. von. Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, Beiträge zur Kentniss des sibirischen Cambrium, p. 53.

[4] Walcott, C. D. Tenth Ann. Rept. U. S. Geol. Survey, 1890, Pt. 1, The fauna of the Lower Cambrian or *Olenellus* zone, pp. 599-602, pls. 50-55.

[5] Toll, E. von. Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., Vol. 8, No. 10, 1899, Beiträge zur Kentniss des sibirischen Cambrium, p. 53.

addition to sixteen species of the Archæocyathinæ, two species of trilobites, *Dorypyge slatkowskii* Schmidt and *Solenopleura ? sibirica* Schmidt. The species of *Dorypyge* is quite unlike *Dorypyge richthofeni* Dames from the Middle Cambrian of Shan-tung, and the *Solenopleura ? sibirica* has no representative in the Chinese Cambrian fauna. He also places *Microdiscus lenaicus* von Toll in the Lower Cambrian along with the Torgoschino limestone fauna.[1] I see no objection to this arrangement, but I would place the fauna as of late Lower Cambrian age. This would bring it in point of time in correlation with the *Redlichia* fauna of the Shan-tung and Pun-jab provinces. The Siberian fauna, however, is that of the lower Cambrian of Australia, Sardinia, and North America. This leads to the conclusion that the Siberian province was quite distinct in Lower Cambrian time from the Shan-tung and Pun-jab provinces, and that, as von Toll so well states, " The Sinio-Siberian sea stood on the one hand in connection with the Pacific-Amercian and on the other with the Atlantic-European."[2]

In Middle Cambrian time a group of trilobites lived in the Shan-tung sea that I have illustrated on plate 15 under the genera *Inouyia* and *Levisia.* Among the species described by von Toll from the limestone on the Lena river is one that appears to come within the genus *Levisia. Ptychoparia czekanowskii* von Toll[3] is exceedingly close to *Levisia agenor* (Walcott) [plate 14, fig. 19] ; and *Ptychoparia meglitzkii* von Toll[4] has the broad, swollen anterior limb, broad free cheeks, and conical glabella of some of the *Inouyia* [plate 14, figs. 9, 12, 13, 15]. Von Toll describes three species of *Microdiscus* and *Agnostus schmidti* from the Lena limestone; also a species of *Hyolithes,* fragments of a trilobite doubtfully referred to *Olenellus,* and two brachiopods, *Kutorgina cingulata* Billings and *? Obolella* cf. *chromatica* Billings.

The general facies of this Lena limestone fauna led von Toll to place it in the Lower Cambrian, but in the absence of forms that are distinctly of Lower Cambrian age there remains a doubt. In any event the fauna is, with the exception of the two trilobites referred to *Ptychoparia* by von Toll, distinct from the fauna of the Shan-tung Province.

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[1] Toll, E. von. Mém. l'Acad. imp. Sci. St. Pétersbourg, 8th ser., vol. 8, No. 10, 1899, Beiträge zur Kentniss des sibirischen Cambrium, p. 54.

[2] Idem, p. 56.

[3] Idem, pl. 1, fig. 1.

[4] Idem, pl. 1, fig. 2.

The two species of trilobites described by Schmidt from the banks of the Wilui[1] as *Anomocare pawlowskii* and *Liostracus ? maydeli,* are clearly Middle Cambrian forms and comparable with species that I have referred to the genus *Anomocarella* [plate 19] in respect to their large eyes and broad glabella, but not in their narrow frontal limb and rounded frontal rim. These trilobites indicate that in Middle Cambrian time there was no direct connection between the Shan-tung and Siberian provinces.

BIBLIOGRAPHY

The accompanying short Bibliography includes the titles of those publications to which reference is made in this paper.

Blackwelder, Eliot. 1907a. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, pt. 1, 1907 (Apr.), chap. 2, pp. 19-58: Stratigraphy of Shan-tung.

——— 1907b. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, pt. 1, 1907 (Apr.), chap. 5, pp. 85-96: Reconnaissance in southwest Liau-tung.

——— 1907c. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, pt. 1, 1907 (Apr.), chap. 12, pp. 265-279: Stratigraphy of the Middle Yang-tzï Province.

——— 1907d. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, pt. 2, 1907 (June), pp. 357-507, pls. 52-63: Petrography and zoology.

Burrard, S. G., and Hayden, H. H. 1908. A Sketch of the Geography and Geology of the Himalaya Mountains and Tibet, pt. 4, 1908, pp. 207-308, pls. 39-50: The Geology of the Himalaya.

Dames, Wilhelm. 1883. China, by Baron von Richthofen, Vol. 4, 1883, pp. 1-33, pls. 1 and 2: Cambrische Trilobiten von Liau-tung.

Deprat, J. 1912. Mémoires du service géologique de l'Indo-Chine, Vol. 1, 1912 (received late in 1913), fasc. 2, Étude géologique du Yun-Nan oriental, Ie partie, pp. 1-370, pls. 1-20: Geologie générale. Accompanied by Atlas.

Etheridge, R., Jr. 1896. Proceedings of the Royal Society of Victoria for 1895, new (2d) ser., Vol. 8, 1896 (Apr.), pp. 52-64: The existence of a Cambrian fauna in Victoria.

——— 1905. Transactions and Proceedings and Report of the Royal Society of South Australia, Vol. 29, 1905 (Dec.), pp. 246-251, pl. 25: Additions to the Cambrian fauna of South Australia.

Foord, A. H. 1890. Geological Magazine, London, Decade 3, Vol. 7, 1890 (March and Apr.), pp. 98-106, 145-155, pls. 4-7. Description of fossils from the Kimberley District, Western Australia.

[1] Toll, E. von. Mem. l'Acad. imp. Sci. St. Petersbourg, 8th ser., vol. 8, No. 10, 1899, Beiträge zur Kenntniss des sibirischen Cambrium, p. 3.

GOTTSCHE, C. 1886. Sitzungsberichte der königlich preussischen Akademie der Wissenschaften zu Berlin, 1886, zw. halb-bd. (June-Dec.), pp. 857-873, p. 8: Geologische Skizze von Korea.

GRÖNWALL, K. A. 1902. Danmarks Geologiska Undersögelse, Række 2, No. 13, 1902, pp. i-ix, 1-230, pls. 1-5: Bornholms Paradoxideslag og deres fauna.

KAYSER, F. H. E. 1883. China, by Baron von Richthofen, Vol. 4, Abth. 1, Abh. 2, 1883, pp. 34-36, pl. 3: Cambrische Brachiopoden von Liau-tung.

LORENZ, TH. 1904. Centralblatt für Mineralogie, Geologie und Palæontologie, 1904, No. 7, pp. 193-194: Ascosomaceae, eine neue Familie der Siphoneen aus dem Cambrium von Shan-tung.

——— 1905. Zeitschrift der deutschen geologischen Gesellschaft, Bd. 58, 1905: Beiträge zur Geologie und Palæontologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der Provinz Shan-tung in China, pp. 5-64, 5 supplements, 2 text figs.: I Teil.

——— 1906. Zeitschrift der deutschen geologischen Gesellschaft, Bd. 58, 1906, pp. 53-108, pls. 4-6, and 55 text figures: Beiträge zur Geologie und Palæontologie von Ostasien unter besonderer Berücksichtigung der Provinz Schan-tung in China; II: Palæontogischer Teil.

MANSUY, H. 1913. Mémoires du service géologique de l'Indo-Chine, Vol. 1, 1912 (received May 8, 1913), fasc. 2, Étude géologique du Yun-nan oriental, II[e] partie, pp. 1-146, pls. 1-25: Paléontologie.

MONKE, H. 1903. Jahrbuch der königlich Preussischen Geologischen Landesanstalt und Bergakademie zu Berlin, Bd. 23, Hft. 1, 1902, Beiträge zur Geologie von Schan-tung, pp. 103-151, pls. 3-9: 1. Obercambrische Trilobiten von Yen-tsy-yai.

REDLICH, K. A. 1901. Memoirs of the Geological Survey of India, Palæontologia Indica, new ser., Vol. 1, No. 1, 1901, pp. 1-13, pl. 1: The Cambrian fauna of the eastern Salt-Range.

REED, F. R. C. 1906. Memoirs of the Geological Survey of India, Palæontolgia Indica, new ser., Vol. 2, pp. 1-154, pls. 1-8: The Lower Palæozoic fossils of the Northern Shan States, Burma.

——— 1910. Memoirs of the Geological Survey of India, Palæontologia Indica, ser. 15, Vol. 7, 1910, No. 1, pp. 1-70, pls. 1-6: The Cambrian Fossils of Spiti.

RICHTHOFEN, F. VON. 1882. China, 1882, Bd. 2, Das Nördliche China, pp. 1-792, pls. 1-8.

——— 1883. China, 1883, Bd. 4, Palæontologischer Theil, 1. Abhand., pp. 31-33, pls. 1, 2: Cambrische Trilobiten von Liau-tung.

SCHMIDT, FR. 1886. Mélanges Physiques et Chimiques tirés du Bulletin de l'Académie impériale des sciences de St. Pétersbourg, Vol. 12, 1886, pp. 407-424, pl. 12, figs. 1-26: Ueber einige neue ostsibirische Trilobiten und verwandte Thierformen.

TATE, R. 1892. Transactions of the Royal Society of South Australia for 1892, Vol. 15, pt. 2, 1892 (Dec.), pp. 183-189, pl. 2: Cambrian fossils of South Australia.

TOLL, E. VON. 1899. Mémoires de l'Académie impériale des sciences de St. Pétersbourg, 8th ser., Vol. 10, 1899, pp. 1-57, pls. 1-8, and 9 text figs.: Beiträge zur Kenntniss des sibirischen Cambrium.

ULRICH, E. O. 1911. Bulletin of the Geological Society of America, Vol. 22, 1911, pp. 261-680, pls. 25-29: Revision of the Paleozoic Systems.

WALCOTT, C. D. 1884a. Bulletin United States Geological Survey No. 10, 1884, pp. 1-74, pls. 1-10: On the Cambrian faunas of North America: Preliminary studies.

——— 1891a. Tenth Annual Report United States Geological Survey, 1890, pt. 1, pp. 509-774, pls. 43-98: The fauna of the Lower Cambrian or Olenellus zone. (This report is dated 1890, but was not issued until well along in 1891.)

——— 1891b. Bulletin United States Geological Survey No. 81, 1891, pp. 1-447, pls. 1-3: Correlation papers, Cambrian.

——— 1899. Bulletin Geological Society of America, Vol. 10, 1899, p. 199: Pre-Cambrian fossiliferous formations.

——— 1905a. Proceedings Washington Academy of Sciences, Vol. 7, 1905 (July 24), pp. 251-256: The Cambrian fauna of India.

——— 1905b. Proceedings United States National Museum, Vol. 29, 1905 (Sept. 6), pp. 1-106: Cambrian faunas of China.

——— 1906. Proceedings United States National Museum, Vol. 30, 1906 (May), pp. 563-595: Cambrian faunas of China, paper No. 2.

——— 1908a. The Canadian Alpine Journal, Vol. 1, No. 2, 1908, pp. 232-248, 5 ills., 4 pls.: Mount Stephen rocks and fossils.

——— 1908b. Smithsonian Miscellaneous Collections, Vol. 53, Cambrian Geology and Paleontology, No. 5, 1908 (Dec.), pp. 167-230, pls. 13-22: Cambrian sections of the Cordilleran area.

——— 1910a. Smithsonian Miscellaneous Collections, Vol. 53, Cambrian Geology and Paleontology, No. 6, 1910 (Aug. 12), pp. 231-422, pls. 23-44: Olenellus and other genera of the Mesonacidæ.

——— 1910b. Smithsonian Miscellaneous Collections, Vol. 57, Cambrian Geology and Paleontology, No. 1, 1910 (Aug. 18), pp. 1-16: Abrupt appearance of the Cambrian fauna on the North American continent.

——— 1911. Smithsonian Miscellaneous Collections, Vol. 57, Cambrian Geology and Paleontology, No. 4, 1911 (June 17), pp. 69-108, pls. 13-17, text figs. 7 and *7a*: Cambrian Faunas of China.

——— 1912. Monographs United States Geological Survey, Vol. 51, 1912, pp. 1-872, pls. 1-104, text figs. 1-76: Cambrian Brachiopoda.

——— 1913. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 3, 1913 (July), pp. 1-276, pls. 1-24, 9 text figs.: The Cambrian faunas of China.

WILLIS, BAILEY. 1907. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol 2, 1907 (July), pp. i-v, 1-133, pls. 1-8: Systematic geology.

——— BLACKWELDER, ELIOT and SARGENT, R. H. 1907. Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, 1907 (Apr.), pt. 1, pp. 1-353, figs. 1-65: Descriptive topography and geology.

WOODWARD, HENRY. 1905. Geological Magazine of London, new ser., Dec. 5, Vol. 2, 1905, pp. 211-215, 251-255, pl. 13: On a collection of trilobites from the Upper Cambrian of Shan-tung, North China.

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 2.—PRE-CAMBRIAN ALGONKIAN ALGAL FLORA

(With Plates 4 to 23)

BY

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CONTENTS

ILLUSTRATIONS

INTRODUCTION

This is a preliminary paper on a fossil algal flora from the Algonkian formations of the Cordilleran area of western America. What has been found as yet appears to have been formed through the agency of algæ closely allied to the Cyanophyceæ (Blue-green Algæ). The associated fauna as it occurs in the Belt series of Montana is illustrated on Plates 21 and 22.

The subject matter is divided into a geologic and a biologic section. The first gives a brief outline of continental conditions and sedimentation of Algonkian time, and the second deals with the algal flora and the traces of a contemporaneous aquatic fauna.

There are a number of algal forms known to me from the Cambrian formations that are allied to *Cryptozoon* and *Collenia* which will not be referred to further in this preliminary paper on the Cordilleran pre-Cambrian forms. The field of investigation is a large one, however, and promises most interesting results.

Acknowledgments.—I am indebted to Mr. M. Collen, who has a ranch on the eastern slope of the Big Belt Mountains south of White Sulphur Springs, for observations on the occurrence of the algal flora in the Newland limestone and Spokane shales. Mr. Collen called my attention to the remarkable forms in the Newland limestone, and made a large collection of material for the United States Geological Survey. I have given his name to a genus that occurs in the Spokane shales in recognition of his great interest and for his persevering search to explain the origin and mode of occurrence of the fossil remains that he suspected to be corals.

In connection with the search for microscopic characters of the algæ, Dr. Albert Mann of Washington took the greatest interest and first discovered cells of the type of those of the Cyanophyceæ, Blue-green algæ (pl. 20, fig. 2), and notwithstanding his many duties made the micrographs of the chains and groups of cells. In the later part of this work he was ably assisted by Mr. Charles Resser of the United States National Museum.

Dr. Charles A. Davis of the Bureau of Mines very kindly advised in relation to the recent fresh-water algæ and their calcareous deposits and called my attention to the remarkable bank deposits in the lakes of Michigan and New York State.

To Dr. John M. Clarke, State Geologist of New York, I am indebted for a small collection of the Lake Balls from Canandaigua Lake, New York, and the electrotype of plate 16.

Dr. George T. Moore, Director of the Missouri Botanical Garden, referred me to authors who had written on the deposition of lime and magnesia through the agency of algæ, and Dr. M. A. Howe of the New York Botanical Garden sent a number of publications bearing on the coralline algæ.

I also consulted with Dr. T. Wayland Vaughan, of the United States Geological Survey, and Dr. Austin H. Clark, of the United States National Museum, in regard to the recent calcareous algæ.

CONTINENTAL CONDITIONS DURING ALGONKIAN TIME

The character and structure of the pre-Algonkian formations[1] indicate that toward the close of the Archeozoic era a period of world-wide diastrophism ensued, resulting in the receding of ocean waters or in the uplift of the American and all other continental masses in relation to the oceans. This great change (Laurentic Revolution) was accompanied or followed by local disturbances which produced profound folding and the metamorphism of the pre-Proterozoic complex, with the formation of mountain ranges, uplands, valleys and lowlands.

Two broad continental geosynclines subparallel to the western and eastern coast lines of the North American continent began to form early in Algonkian (Proterozoic) time. When cut off from the outer oceans or while the surface of these great areas was above the level of marine waters, they received terrigenous Algonkian sediments which began to accumulate on river flood plains and other favorable areas, or were deposited in the epicontinental fresh and brackish water seas or lakes that filled the shallow depressions within the area of the geosynclines. The western or Cordilleran geosyncline extended from the vicinity of the head of the Gulf of California northward probably to the Arctic Ocean.

In Arizona what is left of the Algonkian period of sedimentation is represented by nearly 12,000 feet (3,658 m.) in thickness of sandstones, shales, and limestones of the Grand Canyon group. In Utah and Nevada sediments forming only sandstone and siliceous shale appear to have gathered, while in Montana there is a develop-

[1] Van Hise and Leith, Monogr. U. S. Geol. Survey, Vol. 52, 1911. Table facing p. 598. Also see map 1, accompanying Bull. No. 360, U. S. Geol. Survey, 1909.

ment of limestone 4,800 feet (1,463 m.) in thickness in addition to nearly 20,000 feet (6,093 m.) of siliceous and arenaceous beds.[1] To the north, the Siyeh limestone has a thickness of 4,000 feet (1,220 m.).[2]

In western Alberta and eastern British Columbia to about 54° north latitude the Algonkian sediments are much like those of Montana. In the Montana region of greatest accumulation of Algonkian sediments the Cordilleran trough appears to have been filled to such an extent before Cambrian time, possibly by a river delta, that the Cordilleran Cambrian sea, advancing to deposit its sediments, encountered a central barrier[3] extending out from the eastern side of the trough.

From the Cordilleran trough depressions probably stretched eastward to central Texas, central Colorado, South Dakota, and it may be to the Lake Superior basin.[4]

Briefly summarized, the Algonkian period in North America with its great epicontinental formations was a time of continental elevation and largely terrigenous sedimentation in *non-marine bodies of water,* and of deposition by aerial and stream processes in favorable areas. Marine sediments accumulated in the waters along the outer ocean shores of the continent and great quantities of eruptive matter were extruded into the central Lake Superior region (Keweenawan). The agencies of diastrophism continued to exert their influence for a long period, though with decreasing energy, until they became practically quiescent during the latter part of Algonkian time.

The North American continent was larger at the close of Algonkian time than at any subsequent period other than possibly at the end of the Paleozoic and the end of the Cretaceous, when the land was equally extensive. Indeed, it is highly probable that its area was greater then than even now, for no marine deposits of Algonkian age containing pre-Cambrian life, as they were laid down in

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[1] Bull. Geol. Soc. America, Vol. 17, 1906, p. 7.

[2] Daly has placed the Siyeh limestone of the Algonkian in the Cambrian, but, in the absence of direct areal stratigraphic relations and all Cambrian fossils in the Siyeh limestone, I do not see my way clear to accept his conclusions based on lithologic similarity of the Siyeh and the Middle Cambrian limestones of the Bow Valley and Kicking Horse Canyon.

Rept. Chief Astronomer for year 1910, Ottawa, 1913, Geol. North American Cordillera, Pt. 1, R. A. Daly, pp. 174-178 and accompanying table.

[3] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 169.

[4] See map of Van Hise and Leith (Bull. No. 360, U. S. Geol. Survey, 1909, p. 1).

Lipalian[1] time immediately preceding the Cambrian period, have been discovered on the North American continent or elsewhere so far as known.[2]

Diastrophism.—The most important diastrophic movement within the Cordilleran area in Proterozoic time was the formation and gradual deepening of the great geosyncline extending from the Gulf of Mexico north to the Arctic Ocean. This geosyncline was broader when the Algonkian sediments of the Grand Canyon, Llano, Needle Mountain, Uinta and Black Hills[3] series were being deposited than at the beginning of Cambrian time. Indeed, it is highly probable that it extended eastward to central Texas, Colorado and South Dakota where a depression connected it across the upper Mississippian region with the Lake Superior depression.

Narrowing of the Cordilleran sea.—Before the Lower Cambrian transgression into the Cordilleran area a diastrophic movement began which resulted in a broad geanticline which raised the areas of the Grand Canyon in Arizona, Needle Mountain in Colorado, Uinta in Utah, the Black Hills of South Dakota, and the present site of the Rocky Mountains, above the horizon of wide sedimentary deposition and subjected the region affected by the uplift to erosion during Lower and Middle Cambrian time. This uplift[4] narrowed

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[1] Smithsonian Misc. Coll., Vol. 57, 1910, p. 14 (footnote).

Lipalian (λειπα + αλs) is proposed for the era of unknown marine sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna. It represents the period between the formation of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea.

[2] In this connection the theory of Chamberlin and Salisbury on the cause of the disappearance of the coastal or fringing deposits should be carefully considered by the student. Their conclusion is that "The theoretical continental fringe of sediments has been borne downward and thrust landward by each general deformation, and has crept outward and downward with each relaxation. The whole series is to be regarded as present in the continental shelf and the coast border tract, but as largely concealed by this combination of disturbing processes. When the great depth of the ocean-basins at the edge of the continental shelf is considered, it is obvious that the volume of sediment required to build the shelf seaward is large in proportion to the extension of the shelf, and hence the fringing zone is not very broad." (Geology, Vol. 3, 1906, p. 529.)

[3] Bull. U. S. Geol. Survey, No. 360, 1909, pp. 45, 46.

[4] This movement began some time before the Lower Cambrian transgression, but how long we have no means of determining, as it is not until the beginning of the Upper Cambrian that we find transgressing Cambrian deposits. It also undoubtedly raised the Sierran geanticline west of the Cordilleran area and kept this barrier intact throughout Cambrian time.

the Cordilleran sea on its eastern side and kept it out of the area captured until the Upper Cambrian transgression came. From the distribution of the Algonkian formations enumerated above there must have been a revival of the broad geanticline of early Proterozoic or late Archeozoic time that initiated the Rocky Mountain line of uplift. The pre-Proterozoic geanticline was largely reduced to base level before the first Cambrian transgression and the late Proterozoic uplift resulted in relatively minor stratigraphic disturbance. This is shown by the broad, comparatively low undulations of the Algonkian formations subjected to erosion in Lower and Middle Cambrian time. This late Proterozoic movement on the eastern side of the Cordilleran geosyncline was not as great in the Rocky Mountain area of Canada. This is proven by the Lower Cambrian sea having deposited its sediments over the slightly disturbed Algonkian Bow River series of Alberta.

Coastal deposits.—By coastal or shelf sea deposits I mean the deposits made along the coasts of the Pacific or other oceans either in the open ocean or in bays or other bodies of water in immediate connection with the ocean during Algonkian time. As far as known to me there are no known marine continental fringing or slope deposits or faunas laid down in Algonkian time on or about any of the continents or islands of the world.

A great work of the future will be the finding of marine deposits of Algonkian time and their contained life.

Cambrian basal unconformity.—From the Robson Peak region of British Columbia and Alberta to Arizona and southern California, a distance of over 1,000 miles (1,600 km.), clear evidence of a transgressing Cambrian sea has been found in many localities, proving conclusively that a general unconformity occurs here between the Algonkian and Cambrian. This marked unconformity is the record of the advancing, overlapping Cambrian sea.

Climate.—The presence of great thicknesses of red sandstones and shales in the Algonkian sections of the Grand Canyon and Belt series of Montana suggests an arid and possibly a cold climate. Opposed to this are the great limestone beds which indicate a fair supply of water to form inland seas whose temperature was sufficiently high to permit of an abundant growth of algæ of a simple type that served as the agency for the precipitation of vast quantities of calcareous matter. The only characterizing fossil of this period, possibly of marine derivation, was a crustacean, *Beltina*

danai,[1] which, like the Atlantic coast lobster (*Homarus americanus*), might have lived in quite cold water, or adapted itself to warmer, muddy water, when cut off from marine waters.

In China a cold period near the close of the Algonkian is suggested by the presence of glacial deposits at or below the base of the Man-t'o formation.[2]

ORIGIN OF ALGONKIAN LIMESTONES

The origin of the great pre-Cambrian limestones of western America has long been a mooted question and the nature of the concretionary-like *Cryptozoon* has not been so definitely determined as to be accepted by common consent either as an alga or a Stromatoporoid. Twenty years ago I had a number of thin sections made of the matrix and "fossils" from the limestones of the Chuar terrane of the Grand Canyon series of Arizona[3] and later of specimens from the Belt series of Montana. Not being able to discover any traces of detailed or minute structure I put the specimens and slides aside for future study. Recently I have had occasion to consider the question of the origin of the magnesian limestones of the Algonkian formations of the Cordilleran area and in this connection to determine if possible whether there was any relation between the so-called Cryptozoöns and the presence of the great series of limestones.

As the thought that the entire Algonkian series of western America were of epicontinental origin was forced upon me, I began to doubt the marine origin of the limestones. It then occurred to me to seek further information from the geologists who have been studying the origin of fresh-water calcareous deposits and the paleobotanists acquainted with the calcareous algæ as active agents in secreting and depositing the calcium and magnesian carbonate. The result of these inquiries has led me to the conclusions that the origin of the Cordilleran Algonkian limestones is largely owing to the action of lime-secreting algæ and bacteria and that precipitation of calcium and magnesian bicarbonates from a saturated solution is of very rare occurrence and not an important agent of deposition in geologic time and that marine waters are not necessary for the deposition of magnesian limestones.

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[1] Bull. Geol. Soc. America, Vol. 10, 1899, p. 239, pls. 25-27.

[2] Willis, Research in China, Vol. 2, 1907, p. 39.

[3] *Cryptozoan ? occidentale* Dawson, Bull. Geol. Soc. America, Vol. 10, 1899, pp. 232-234, pl. 23, figs. 1-4.

Recent calcareous deposits.—In discussing with Dr. Charles A. Davis of the United States Bureau of Mines the question of the origin of calcareous deposits in fresh and brackish waters, he called my attention to the Natural History of Marl in volume 8 of the Geological Survey of Michigan.[1]

Dr. Davis here disposes of the theory that the mineral salts are deposited as the result of certain portions of the lake waters reaching the saturation point by showing that the outflow of the lakes is practically the same as the inflow and that the loss by evaporation is too small a factor to be taken into account. He considers the possibility of the plant and animal organisms living in the waters of the lakes being the agents which bring about the results of the deposits of the soluble calcium bicarbonate as the insoluble carbonate. He shows that the deposits of marl that were largely contributed to by Mollusca and other invertebrate shells are of minor importance, and that the commercially valuable calcareous marl deposits do not contain recognizable shell fragments in any preponderance, usually not to exceed 1.04 per cent.

Next, considering the action of plants as precipitating agents for calcium salts, he gives the following two possible general causes for the formation of the lime incrustation upon all aquatic plants:[2]

> All green plants, whether aquatic or terrestrial, take in the gas, carbon dioxide, through their leaves and stems, and build the carbon atoms and part of the oxygen atoms of which the gas is composed into the new compounds of their own tissues, in the process releasing the remainder of the oxygen atoms. Admitting these facts, which are easily demonstrated by any student of plant physiology, we have two possible general causes for the formation of the incrustation upon all aquatic plants.
>
> If the calcium and other salts are in excess in the water, and are held in solution by free carbon dioxide, then the more or less complete abstraction of the gas from the water in direct contact with plants causes precipitation of the salts upon the parts abstracting the gas, namely, stems and leaves. But in water containing amounts of the salts, especially of the calcium bicarbonate, so small that they would not be precipitated if there were no free carbon dioxide present in the water at all, the precipitation may be considered a purely chemical problem, a solution of which may be looked for in the action upon the bicarbonates, of the oxygen set free by the plants. Of these, calcium bicarbonate is the most abundant, and the reaction upon it may be taken as typical and expressed by the following chemical equation:

$$CaH_2(CO_3)_2 + O = H_2O + CaCO_3 + CO_2 + O$$

$$\left.\begin{array}{l}\text{calcium}\\\text{carbonate}\end{array}\right\} + \text{oxygen} = \text{water} + \left\{\begin{array}{l}\text{calcium}\\\text{carbonate}\end{array}\right\} + \left\{\begin{array}{l}\text{carbon}\\\text{dioxide}\end{array}\right\} + \text{oxygen}$$

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[1] Geol. Survey Michigan, Vol. 8, part 3, 1903, pp. 65-96.

[2] Idem, p. 69.

in which the calcium bicarbonate is converted into the normal carbonate[1] by the oxygen liberated by the plants, and both carbon dioxide and oxygen set free, the free oxygen possibly acting still farther to precipitate calcium monocarbonate.

He concludes that the alga *Chara* is the great agent for the concentration and precipitation of the calcium carbonate, and that the Blue-green algæ are also largely concerned in the formation of the massive beds of lake tufa and the calcareous pebbles which show both radial and concentric structure. Dr. Davis describes the pebbles as roughly ellipsoidal in shape, the radial lines shown in the sections [Idem, p. 91] being formed by the growth of the filaments while the concentric lines probably represent periods of growth of the plants either seasonal or annual. Included within this structure are great numbers of plants, besides the lime-secreting *Zonotrichia* and considerable numbers of diatoms. These pebbles have quite a wide distribution in the lakes of Michigan, Wisconsin and elsewhere.

Those interested should consult Dr. Davis's paper on the mineral deposition of calcium carbonate through the agency of algæ, also Dr. John M. Clarke's paper on "Water Biscuit."[2] Dr. Clarke kindly sent me specimens of the "Water Biscuit" from Canandaigua Lake. A number of transverse sections were made of these, some of which show a very distinct concentric structure (pl. 14). Dr. Clarke in describing the origin of the "Water Biscuit" states that:[3]

It is quite clear that the process of formation of these peculiar bodies has been the following. The beach shale and débris have become incrusted by a growth of algæ, and the latter, stealing away for their requirements the excess of free carbon dioxide in the water necessary to keep the carbonate of lime in solution, have thus caused a precipitation of the lime salts. The process has been continuous, as when a new precipitation formed a concentric continuous deposit of lime carbonate, the new surface became coated with the algæ and in consequence fresh precipitation followed. The whole forms a most interesting instance of the influence of plant growth on the formation of lime deposits.

At my request Dr. Davis gave me the following notes on the calcareous deposits in Green and Round Lakes, situated two miles (3.2 km.) southwest of Kirkville, Onondaga County, New York:

These lakes are located in a deep valley which is apparently rock walled, with the rocks covered from four to ten feet, apparently, with drift. The walls of the valley are wooded and may be a hundred or more feet high. Green

[1] Which is only very slightly soluble, 100 parts to the million.

[2] Bull. N. Y. State Mus., No. 39, Vol. 8, 1900, pl. 14, pp. 195-198, pls. 12-15.

[3] Idem, p. 197.

Lake is reported to be about 125 feet deep at the deepest part by Mr. C. M. Crouse, of Syracuse, who has sounded it. The rock seen in the ravines at the head of Round Lake was a gray, rather thin-bedded limestone, not much weathered or disintegrated. Fragments of the wall rock are abundant in the drift.

The region around the valley, judging from the shape of the hills, is morainal. A considerable stream connects the two lakes and flows out from Green Lake through an artificial, straightened and deepened channel which has been cut through a swamp. This ditch cuts through beds of tough white and rather porous calcareous tufa and beds of loose granular marl. Tufa also appears in great blocks on the sides of the principal ravine leading out from the head of Round Lake near the rock outcrops but none was seen in the lake.

In Green Lake considerable spaces along the shore have deposits of tufa which extend out into the lake from the shore for as much as twenty feet, or more in places, forming perpendicular or overhanging sub-aquatic cliffs or terraces. These terraces extend from slightly above the surface, at the stage of water when visited, to below the level to which one can see through the greenish, somewhat turbid water. The terraces are covered, wherever examined, with an incrustation of calcareous marly substance, which shows bluish-green wherever it is freshly broken, especially near the surface. This covering layer is, in general, weakly cemented and friable and is easily scraped from the more consolidated portions which it sometimes covers to the depth of an inch or more. This living layer covers not only the rock, but other substances which are in the water, often coating branches of fallen trees to a thickness of one to two inches, while stumps of trees which are favorably located often appear like heads of coral near the water surface.

In two places, logs of white cedar (*Thuja*) were noted which were completely imbedded in the solid faces of the cliff and projected from them. One of these logs passed diagonally through the deposit, appearing both above and below it. In many cases the dead trees and branches form dense mats on sides of the steep wall of the lake below water level and are apparently in the process of being covered with the algal incrustation, as there are thick deposits of the limy matter characteristic of these in many places. It may be that these collections of woody débris form the foundations on which the terraces which have developed have been started.

Specimens broken from the underlying tufa show a considerable amount of porosity, but the limestone from the terraces is not friable like the incrustation, although apparently of the same origin, since some of the twigs included in it run through both hard and soft material. The under sides of fragments of the compact rock which lie submerged on the surface of the terraces often appear to have botryoidal structure.

The tufa of the terraces is quite different in appearance and apparent origin from that in the valley below the lake. *Chara* remains are frequent in the tufa of the ditched level, but none were noted in the material forming the terraces, and no *Chara* was seen in the lake, except in the outlet, and that was but slightly incrusted with lime.

The occurrence of the terraces in spots along the lake suggests special reasons for the development of these terraces at certain points, but no such reasons appear from casual examination. A slightly higher level than that at

present held was apparently indicated by a small terrace which appears a foot or 18 inches above the present level of the water, and the limy deposit was apparently formed at this level as well as at the present one.

It was noted that the branches of trees and other drift material which had settled to the bottom of the lake were covered by the incrusting algal deposits as far down as twelve or fifteen feet. These fragments may possibly have rolled down the steep slope after the formation of the incrustation, but of this there was no good evidence visible. If deposition as the result of the activities of the algæ went on faster near the water surface, as theoretically it should, since here the plants find most favorable light conditions, the peculiar overhanging form of the terraces might easily result. This type of deposit is what should theoretically result from the work of *Zonotrichia,* if it grew under very favorable conditions and in great abundance. It is probable, from the color of the broken fragments, that the algæ are responsible for the formation of the whole of these deposits, or for most of them.

Further work on the identity of the Blue-green alga most abundant in the spongy calcareous covering of one of the branches which was collected at the time of my visit to the locality shows that the organism is a cellular Blue-green alga, and not a filamentous one like *Zonotrichia.* This cellular type develops irregular aggregations of rounded or oval, very small cells, which apparently seldom arrange themselves in strings. The genus or species has not been identified.

Mr. G. W. W. Barclay, when describing some "Algoid Lake-balls" that he found in Loch Kildonan in the Hebrides,[1] states that the balls are from a quarter of an inch to 3 or 4 inches in diameter and lie side by side in great numbers. In some cases a complete small ball is found inside a larger one and the balls while usually spherical may be irregular in shape. He found them composed of innumerable algal filaments, so intertwined and matted together as to form an outer covering of an almost felt-like consistency that is about one-twentieth to two-twentieths of an inch in thickness. The interior seems to consist of mud but the microscope shows that they are composed of a filamentous alga (*Cladophora glomerata*). The decomposed remains of the inner ends of the filaments are mingled with diatoms, but there does not appear to be any calcareous matter present.

Somewhat similar lake balls have also been found in several other European lakes.

Mr. A. C. Seward in his "Fossil Plants"[2] writes as follows:

> On the shores of the Great Salt Lake, Utah, there are found numerous small oölitic calcareous bodies thrown up by the waves.[3] These are coated with the

[1] Proc. Royal Soc., Edinburgh, 1886, Vol. 13, pp. 845-848, pl. XXX.

[2] Cambridge Univ., Press, Vol. 1, 1898, pp. 122, 123.

[3] Rothpletz, A.; Über die Bildung der Oolithe, Bot. Cent., Vol. 51, p. 265, 1892.

cells of *Glœocapsa* and *Glœotheca,* two genera of the Chroococcaceæ. Sections of the grains reveal the presence of the same forms in the interior of the calcareous matrix, and it has been concluded on good evidence that the algæ are responsible for the deposition of the carbonate of lime of the oölitic grains. By extracting the carbonic acid which they require as a source of food, from the waters of the lake, the solvent power of the water is decreased and carbonate of lime is thrown down. In similar white grains from the Red Sea [1] there is a central nucleus in the form of a grain of sand, and cells of Chroococcaceæ occur in the surrounding carbonate of lime as in the Salt Lake oölite.

The analyses of the Michigan Lake deposits show from 2 to 13 per cent of magnesian carbonate, the amount varying with the magnesian content of the lake water. The amount of calcium and magnesium carbonate is determined by the amount of the two minerals available for solution in the rocks and soils of the drainage basin tributary to the pond or lake in which the deposits occur.

Algonkian lakes.—The lakes of Algonkian time were not much if any larger in area than the "Great Lakes" of the St. Lawrence drainage basin and they were much shallower and more laden with mud and mineral matter in solution.[2]

The area of the Belt terrane in Montana is about 6,000 square miles. This seems large when studying it in the field, but it is only one-fifth of the size of our great fresh-water Lake Superior.[3]

DEPOSITION OF LIMESTONE THROUGH THE AGENCY OF ALGÆ

The drainage into the Algonkian lakes undoubtedly afforded all of the soluble mineral matter necessary to account for the limestones, siliceous shales and sodium chloride deposits of the Algonkian series of formations.[4]

From a study of the water of the principal rivers of the world Sir John Murray compiled the following table, showing the average amount of mineral matter in solution in one cubic mile of average river water. [Scottish Geol. Mag., Vol. 3, 1887, p. 76.] The propor-

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[1] Walther, J., Die Korallenriffe der Sinaihalbinsel, Abh. math. phys. C. K. Sächs. Ges., Vol. 14, 1888.

[2] Geology, Chamberlin and Salisbury, Vol. 1, 1904, p. 102.

[3] Lake Superior has an estimated area of 32,060 square miles. It is 400 miles long and 160 miles wide. The combined area of the five great lakes is estimated at 94,605 square miles.

[4] For the areas of the known Algonkian deposits see plate 1 accompanying report of Van Hise and Leith on pre-Cambrian Geology of North America, Bull. U. S. Geol. Survey, No. 360, 1909.

tionate amount have varied in the river waters of Algonkian time, but probably it was essentially similar in composition and larger in quantity.

Constituents.	Tons in a Cubic Mile.
Calcium carbonate ($CaCO_3$)	326,710
Magnesium carbonate ($MgCO_3$)	112,870
Calcium phosphate ($Ca_3P_2O_8$)	2,913
Calcium sulphate ($CaSO_4$)	34,361
Sodium sulphate (Na_2SO_4)	31,805
Potassium sulphate (K_2SO_4)	20,358
Sodium nitrate ($NaNO_3$)	26,800
Sodium chloride ($NaCl$)	16,657
Lithium chloride ($LiCl$)	2,462
Ammonium chloride (NH_4Cl)	1,030
Silica (SiO_2)	74,577
Ferric oxide (Fe_2O_3)	13,006
Alumina (Al_2O_3)	14,315
Manganese oxide (Mn_2O_3)	5,703
Organic matter	79,020
Total dissolved matter	762,587

Many authors have written on the limestone-forming algæ that should be referred to in a memoir on the subject, but in this preliminary paper on the Algonkian forms of the Cordilleran area only a few will be noticed.

In a recent paper on "The Important Part Played by Calcareous Algæ at certain Geological Horizons"[1] Professor E. J. Garwood gives a brief historical account of the genera and then discusses the influence of algæ in the formation of sedimentary rocks. He mentions the presence of oölites in the Archean and Algonkian rocks.[2] Very few traces have been found in Cambrian rocks, but in the Ordovician they become much more abundant. He does not mention the Cambrian genus *Cryptozoon*. After reviewing the algæ of geologic time Professor Garwood concludes that it plays a very important part as rock builders at many different horizons in the geologic series; that certain forms are restricted to definite geologic periods, but that they had a wide geographic range. He calls attention to the constant association of fossil calcareous algæ with oölitic structure and also with dolomite. In regard to the latter he says:[3]

The presence of dolomites in connection with algal growths at different geological horizons appears to show that the beds have accumulated under

[1] Geol. Mag. n. s., Dec. 5, Vol. 10, 1913; pp. 440-446, 490-498, 545-553.

[2] Idem, p. 491.

[3] Idem, pp. 552-553.

definite physiographical conditions similar to those which obtain to-day in the neighborhood of coral reefs. Such lagoon conditions would tend to come into existence during periods of subsidence or elevation, and this is just what we find when we examine the periods at which these reefs are most persistent.

Thus the Girvan Ordovician lagoon-phase occurred during an elevation which culminated with the deposition of the Benan Conglomerate; the Lower Carboniferous "Algal band" in Westmorland was laid down during the subsidence which followed the Old Red Sandstone continental period, while the Upper *Girvanella* Nodular band occurred when the marine period of the Lower Carboniferous was drawing to a close and a general elevation was taking place. Similar conditions could be drawn from the Gotlandian and other periods recorded above.

A table which shows the known occurrence of fossil algæ from the Cambrian to the late Tertiary accompanies the paper.

A brief paper by Dr. Marshall A. Howe of the New York Botanical Garden on "The Building of Coral Reefs,"[1] cites a number of writers to sustain his contention that the calcareous algæ are the largest contributors to the building of the "Coral Reefs and Islands." Dr. Howe in summing up on his subject says:

With the dominance in reef-building activities resting sometimes with the calcareous algæ and sometimes with the corals, and with the Foraminifera and other groups also playing their parts, the problem of determining the "most important" constructive element in the calcium carbonate reefs of the world, ancient and modern, is naturally a most complicated and difficult one, and one that may never be solved to the full satisfaction of those most interested.[2]

As an illustration of the dominance of the lime secreting plants he quotes Prof. J. Stanley Gardiner as follows:

The reefs of the Chagos are in no way peculiar, save in their extraordinary paucity of animal life . . . . . However, this barrenness is amply compensated for by the enormous quantity of nullipores (*Lithothamnia,* etc.) incrusting, massive, mammillated, columnar and branching. The outgrowing seaward edges of the reefs are practically formed by their growths and it is not too much to say that were it not for the abundance and large masses of these organisms, there would be no atolls with surface reefs in the Chagos.[3]

Again he quotes Professor Seward's summary of the results of J. Walther's studies of a *Lithothamnion* bank in the Bay of Naples about 30 m. below the surface of the water:

By action of the percolating water the *Lithothamnion* structure is gradually obliterated, and the calcareous mass becomes a structureless limestone.

[1] Science, n. s., Vol. 35, 1912, pp. 837-842.

[2] Idem, p. 842.

[3] Trans. Linn. Soc. London, Zool., 2d ser., Vol. 12, pp. 177, 178, 1907. Also, Nature, Vol. 72, pp. 571, 572, where a photograph of this *Lithothamnion* reef is published.

Walther applies his knowledge of this recent algal deposit to the examination of a Tertiary "Nulliporenkalk" near Syracuse. In many parts of this formation there occur well-preserved specimens of *Lithothamnion*, but in others a gradual obliteration is observed of all plant structures until the rock becomes entirely structureless. A similar instance of structureless limestone is described from the Lias of Todten Gebirges [Todtes Gebirge].[1]

In an interesting paper on the "Origin of the Bighorn Dolomite"[2] Dr. Eliot Blackwelder considers the influence of calcareous algæ in the deposition of this Ordovician dolomite. After a very clear discussion he concludes that an alga of the type of the modern coralline alga *Lithophyllum* is the most likely form to have made the structure that is very widely present in the dolomite. The absence of microscopic cells is explained by the crystallization of the dolomite. Of the branching structures he says, "It seems more likely that they represent banks of calcareous algæ than any of the plant-like animals."[3]

One of Dr. Blackwelder's illustrations (pl. 33, fig. 1) suggests a form allied to *Greysonia basaltica* (pl. 17, fig. 2; pl. 18, fig. 2) of the Newland limestone. There is to me no apparent reason why the blue-green algæ (Cyanophyceæ) should not have lived in the marine waters in which the Big Horn dolomite was deposited and also reproduced forms allied to those of the Algonkian. This comment is made with the hope that a thorough search will be carried on throughout the Palæozoic group for forms resembling those of the Belt series of limestones.

Bacterial deposits.—Dr. Alfred G. Mayer in speaking of the work of the late Mr. George H. Drew wrote as follows:[4]

> In 1910, Sanford, and also Vaughan, published the conclusion that a considerable portion of the calcareous muds in the bays and sounds of southern Florida was precipitated out of the sea-water in some unknown manner. It remained for Drew, in 1911, to discover that there is in the warm surface waters of the West Indian and Florida region, and especially in the limestone mud itself, a bacillus which deprives the sea-water of its nitrogen, thus causing the calcium to combine with the dissolved carbon dioxide and to form the finely-divided limestone mud so characteristic of coral-reef regions. Drew isolated this bacillus and found that it became inactive in even moderately cold water, and thus it functions only in warm or tropical seas, thriving best at depths of less than 100 fathoms. In the surface waters of the Bahamas and Florida it is the most abundant marine bacillus.

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[1] Gardiner, "The Fauna and Geography of the Maldive and Laccadive Archipelagos," Vol. 2, pp. 10-26.

[2] Bull. Geol. Soc. America, Vol. 24, pp. 607-624, pls. 28-35.

[3] Idem, p. 624.

[4] Papers from the Tortugas Laboratory, Carnegie Institution of Washington, Vol. 5, 1914. p. 5.

In the paper by Drew "On the Precipitation of Calcium Carbonate in the Sea by Marine Bacteria" there are two paragraphs that sum up the results of his work.[1]

The observations so far available are too few, and the area they cover too small, to attempt to make any broad generalization at present. However, it can be stated with a fair degree of certainty that the very extensive chalky mud flats forming the Great Bahama Bank and those which are found in places in the neighborhood of the Florida Keys are now being precipitated by the action of the *Bacterium calcis* on the calcium salts present in solution in sea-water. From this the suggestion is obvious that the *Bacterium calcis,* or other bacteria having a similar action, may have been an important factor in the formation of various chalk strata, in addition to the part played by the shells of Foraminifera and other organisms in the formation of these rocks. Dr. T. Wayland Vaughan has also suggested that the Miami oölite and other oölitic rocks may owe their origin to the occurrence of some diagenic change in the precipitate of very finely divided particles of calcium carbonate produced in this way by bacterial action. If this view as to the formation of chalk and oölite rocks is correct, it would seem probable that these strata must have been deposited in comparatively shallow seas whose temperature approximated to that of tropical seas at the present time. . . . .

As it now stands, the investigation can, at most, be considered to offer a mere indication of the part played by bacterial growth in the metabolism of the sea. To obtain a real insight into the question, it would be necessary to make more extensive bacterial and chemical observations in tropical, temperate, and arctic waters, to study the bacteriology of other areas where calcium carbonate is being precipitated from the sea, and to make further investigations in the laboratory into the chemistry of the reactions that can be brought about by various species of marine bacteria.

Dr. T. Wayland Vaughan in discussing the formation of the Floridian and Bahaman oölites before the Geological Society of Washington said:[2]

The studies of Dall, Sanford, and the author, in association with Geo. C. Matson, led to the opinion that the finely divided calcium carbonate oozes so abundant in Florida waters are chemical precipitates. Drew showed in 1911 that denitrifying bacteria are an important agent in effecting this precipitation in Florida waters; and in 1912 he extended his researches to the Bahamas, where he found them enormously abundant and active, as many as 160,000,000 being found in 1 cc. of surface mud on the west side of Andros Island. Rainey, in 1858, Harting, in 1871, and Linck, in 1903 (and perhaps others), showed that calcium carbonate precipitated by an alkali forms spherulites; and Drew noted a similar tendency of the calcium carbonate precipitated on his cultures. Murray and Irvine showed that at higher temperature chemically precipitated calcium carbonate is of the aragonite form. . . . .

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[1] Papers from the Tortugas Laboratory, Carnegie Institution of Washington, Vol. 5, 1914, p. 44.

[2] Journ. Washington Acad. Sci., Vol. 3, 1913. p. 302-304.

Although there is need for additional study of the factors that accelerate, retard, or inhibit the formation of spherulites and the growth of the grains, the empirical facts in the process of the formation of the Floridian and Bahaman oölites are demonstrated. They are as follows: (1) Denitrifying bacteria are very active in the shoal waters of both regions and are precipitating enormous quantities of calcium carbonate which is largely aragonite; (2) this chemically precipitated calcium carbonate may form spherulites which by accretion may become oölite grains of the usual size, or it may accumulate around a variety of nuclei to build such grains. . . . .

Drew's unfortunately incompleted studies of the distribution of denitrifying bacteria have shown them to be the most prevalent in the shoal-waters of the tropics. They therefore conform to the principles enunciated by Murray for the distribution of lime secreting organisms. By combining the results of Drew and Murray, the deduction seems warranted that great limestone formations, whether they be composed of organic or of chemically precipitated calcium carbonate, were laid down in waters of which at least the surface temperatures were warm, if not actually tropical.

Application.—The limestones of the Newland formation have more or less magnesian content, but many of the layers are pure limestone especially those containing the reefs or banks of algæ. The specimens of algæ are usually magnesian and siliceous which accounts for the weathering in relief, and the ease by which they are brought into relief by the solution of the limestone in weak hydrochloric acid.

The purer limestones are of considerable vertical thickness and their distribution indicates bodies of water several thousand square miles in area. The banks or reefs of algal deposits make a small percentage of the total mass of limestone, but if we assume, as I think we may, that the Bacteria were active agents in the deposition of the soluble bicarbonate of lime in the Algonkian waters, a plausible explanation is found for the occurrence of the homogeneous limestones of the Algonkian in which no traces of fossils have been found. The presence of a well-developed Blue-green algal flora in the Algonkian limestones prepares one for the view that the still more primitive Bacteria were in existence and at work in the epicontinental Algonkian waters.

Dr. Clement Reid in an article on Palæobotany states that:[1]

the first evidence for the existence of Palæozoic Bacteria was obtained in 1879 by Van Tieghem, who found that in silicified vegetable remains from the Coal Measures of St. Étienne the cellulose membranes showed traces of subjection to butyric fermentation such as is produced at the present day by *Bacillus Amylobacter*; he also claimed to have detected the organism itself. Since that time a number of fossil Bacteria, mainly from Palæozoic strata, have been described by Renault, occurring in all kinds of fossilized vegetable and

[1] Ency. Brit., 11th ed., Vol. 20, 1911, p. 525.

animal débris. The supposed *Micrococci* present little that is characteristic; the more definite, rod-like form of the *Bacilli* offers a better means of recognition, though far from an infallible one; in a few cases dark granules, suggestive of endospores, have been found within the rods. On the whole, the occurrence of Bacteria in Palæozoic times—so probable a priori—may be taken as established, though the attempt to discriminate species among them is probably futile.

It may be that traces of bacteria will be found in the Algonkian limestones when the investigations now planned are carried to completion.

The carbonaceous matter in the dark Newland limestones is shown by the black, floculent residue that accumulates when a fragment of limestone is dissolved in hydrochloric acid, and in the field by the bituminous odor given off when the rock is struck with a heavy hammer. The carbonaceous matter of the Bacteria and Algæ was probably the source of that occurring in the limestone.

MAGNESIAN LIMESTONES

The presence of thick deposits of magnesian limestone in the Algonkian, leads to the conclusion that the magnesium content of Algonkian river and epicontinental bodies of water was not far from what it is to-day. Dr. Stuart Weller asks the question, "Are the Fossils of the Dolomites indicative of Shallow, highly Saline and Warm Seas?"[1] He compared the faunas of the dolomitic Galena formation of the upper Mississippi region with that of the Trenton limestone of the eastern or Atlantic region. He concludes that from these comparisons there is

no evidence whatever for concluding that the life conditions in the Galena sea were in any respect different from those of the basins which are now represented by purely calcareous sediments. There is no single characteristic of the fauna which would suggest that the waters were more saline, warmer, or shallower that the seas in which, for instance, the Trenton limestone of the East or the Kimmswick limestone of southern Illinois and Missouri were deposited. It is ordinarily conceded that an intensification of the salinity of sea waters produces a depauperation of the faunas, but the fauna of the Galena is notably composed of the larger and more robust forms, probably because the smaller and more delicate shells have been obliterated by secondary chemical changes in the sediments.[2]

His summary is that,[3]

in conclusion, it may be stated from the evidence of the fossils alone there seems to be no reason for assuming that our widespread dolomitic

[1] Bull. Geol. Soc. America, Vol. 22, 1911, p. 227.

[2] Idem, pp. 229-230.

[3] Idem, p. 231.

formations of Paleozoic age have been deposited under conditions which are notably different, as regards salinity, temperature, or depth, from those under which non-magnesian formations, either argillaceous or calcareous, have been laid down. Chemical geologists are almost unanimously agreed that in general the dolomitization of limestone is a secondary process, and the paleontological evidence, so far as it is available, seems to substantiate that view. Formations now dolomite were in all probability originally deposited as limestones, and have been altered to dolomites since their original deposition, while other beds entirely similar in original condition have not been modified, but persist to the present time as true limestones.

Thus far my observations have led to practically the same conclusion for the Algonkian and Cambrian magnesian limestones. There was in all probability a small percentage of magnesian salts deposited through the agency of Bacteria and Algæ in the epicontinental Algonkian sediments, but it was a secondary process that produced the limestones with a high percentage of magnesia.

Definition of magnesian limestone and dolomite.—In response to my request Mr. E. F. Burchard, of the United States Geological Survey, sent the following note on magnesian limestone and dolomite. I think it would be well if some such classification of the magnesian rocks could be generally accepted, as the term dolomite has been very loosely used in geologic literature:

Magnesian limestone.—Magnesian limestone is limestone containing magnesium carbonate in any quantity up to 45.65 per cent. The majority of magnesian limestones carry either a small percentage or a high percentage of magnesium carbonate, although there are many deposits that are intermediate in composition.

Dolomite.—Dolomite is a mineral composed of the double carbonate of calcium and magnesium ($CaCO_3 \cdot MgCO_3$). It contains 54.35 per cent $CaCO_3$ and 45.65 per cent $MgCO_3$. In practice, magnesian limestone, containing 20 per cent or more of magnesium carbonate generally has been called dolomite, but it would be preferable if magnesian limestone could be distinguished as "low magnesian" and "high magnesian," restricting the term dolomite to rock containing nearly, if not quite, the theoretical quantity of magnesium carbonate necessary to combine with the calcium carbonate in the proportions given above, or in the ratio of 1 : 1.19. The mineral dolomite in places form rock masses, in which the crystals of dolomite can be distinguished. In some rocks these crystals make up a large proportion of the beds, and on weathering, the rock crumbles to a sand composed of dolomite crystals. Rock and sand of this character are common in southwest Wisconsin near the junction of Wisconsin and Mississippi rivers. The texture of magnesian limestone and so-called dolomite is commonly rather rough and moderately coarse on weathered surfaces.

In the formation of magnesian limestone and dolomite, magnesium carbonate is believed to have replaced calcium carbonate, either while the beds were being deposited in the sea, or after the beds become part of the land surface.

The degree of replacement is variable, and ranges from less than one per cent to 45.65 per cent, although most commonly found to be either low or high. Limestone containing a higher percentage of magnesium carbonate than true dolomite may be termed "super-magnesian" limestones, and if all the calcium carbonate is replaced by magnesium carbonate the rock becomes magnesite. This process of replacement is known as dolomitization, and is accompanied by contraction or shrinkage of about 12.3 per cent[1] of the volume of the original limestone. This contraction is believed to produce porosity in the rock under conditions where the pressure is not sufficiently great to close the pores of the rock.

THE BIOTIC RECORD

The fauna.—The biotic record and character of the Algonkian rocks included in the Grand Canyon, Llano, and Belt series of the Cordilleran region, and in formations correlated with them,[2] prove that the marine waters of the extra-continental seas very rarely had access to the epicontinental seas and lakes in Algonkian time. Such connection appears to have been established in mid-Beltian time when at least a crustacean, and a few annelids penetrated into and became adapted to the conditions of the Montana-Alberta sea, and more or less similar forms to the Arizona sea.[3] Other and different forms may have lived in these and other interior bodies of water, but as yet we have no knowledge of them.

The vertical range of the small Beltian (Algonkian) fauna is limited to a few hundred feet of strata in the Cordilleran area, a fact which tends to demonstrate that the environment was not favorable to its development and survival for any considerable period.

The most satisfactory explanation of the absence of a characteristic marine life in Algonkian deposits is the probability that all the known rocks of Algonkian time are of non-marine origin and hence could not have had the opportunity to embed a marine fauna except as few marine species gained access to the epicontinental seas and quickly disappeared.

The existence of a large and varied marine life (Lipalian) in the extra-continental pre-Cambrian seas is inferred from the occurrence of a highly organized and varied fauna in Lower Cambrian time in both the Cordilleran and Appalachian geosynclines. The worldwide distribution of the Lower Cambrian fauna also indicates the great antiquity of the fauna from which it was derived.

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[1] Van Hise, C. R., A treatise on metamorphism; U. S. Geol. Survey, Monogr. 47, 1904, p. 806.

[2] Bull. U. S. Geol. Survey, No. 350, 1909, pp. 42-46.

[3] Bull. Geol. Soc. America, Vol. 10, 1899, pp. 199-244.

The practically entire absence of the types of the Cambrian fauna from all Algonkian rocks not only on the North American continent but all continents is so significant that it is to me very strong evidence that there was no sustained connection between the great oceans swarming with a highly developed invertebrate life and the epicontinental bodies of water in which the Algonkian limestones and shales were deposited.

The fauna of the Lower ? Huronian of Steeprock Lake, western Ontario, was presumably derived from a marine fauna and possibly lived under brackish-water conditions. The principal species of the Steeprock Lake pre-Cambrian fauna, *Atikokania lawsoni*,[1] is probably a spongoid of a rather advanced stage of development, although it suggests the Archæocyathinæ. We are here given a glimpse of a fauna that existed near the base of the (Algonkian) Proterozoic and which must have had its beginnings in Archeozoic time. It further indicates the presence of a sufficient supply of calcareous matter in this inland water to form its skeleton and also a massive limestone deposit in which its remains now occur. This also implies calcareous beds in the great unknown Lipalian deposits of marine waters on the borders of the continents.

The recognized animal life includes several species of annelids and one large species of crustacean that occur in the Greyson shales just above the Newland limestone. This fauna is illustrated in plates 21 and 22 of this paper. It was described along with doubtful forms from the Grand Canyon series in 1899.[2]

Algal deposits.—The presence of an abundant algal flora is proven by thick layers formed of the remains of *Collenia* (*Cryptozoan*[3] in former reports) in the Grand Canyon section where representatives of the genus occur in limestones separated by 1500 feet (460 m.) of intervening strata. In the Camp Creek section of Montana *Collenia* was found to range up through 2,500 feet (760 m.) of strata.[4]

In the Blackfoot series the vertical range is over 2,800 feet (850 m.). In 4 of the section fine specimens of *Collenia* two feet (0.6 m.) and more in diameter occur in beds 3 feet (1 m.) thick.[5] These and beds near the Lewis and Clark Pass are reefs formed by calcareous algæ.

[1] Appendix to Memoir No. 28, Geol. Survey, Canada, 1912, p. 4.

[2] Bull. Geol. Soc. America, Vol. 10, 1899, pp. 232-239.

[3] I do not know a true Cryptozoön older than the Cambrian fauna.

[4] Bull. Geol. Soc. America, Vol. 17, 1906, pp. 4-5.

[5] Idem, p. 6.

The Newland limestone of the Belt series is about 2,000 feet (630 m.) in thickness and the algal forms are reported by Collen as occurring in it from base to summit. These include *Newlandia, Greysonia, Camasia,* etc. *Collenia* is abundant in the Spokane shales 3,000 to 4,000 feet (960 to 1200 m.) above the Newland limestone.

The preceding examples prove that the algal forms extend through several thousand feet of strata and that they are so abundant as to form reefs or banks of fossil algæ in the section.

Stratigraphic position.—As the principal groups of fossils occur in the Beltian series of formations the typical section is introduced here and the position of the genera indicated as they occur in the several formations. The section is one obtained during a reconnaissance of the Belt Mountains in 1898. The thickness assigned to the various formations is based on fairly careful reconnaissance estimates.[1]

SECTION OF BELT SERIES

Cambrian—Flathead sandstone.

	Feet	
Unconformity		
Marsh shales	300	
Helena limestone	2,400	
Empire shales	600	
Spokane shales	1,500	*Collenia undosa*
Greyson shales	3,000	*Annelid trails,* 5 spp. *Beltina danai*
Newland limestone	2,000	*Newlandia concentrica* *Newlandia frondosa* *Newlandia lamellosa* *Newlandia major* *Camasia spongiosa* *Weedia tuberosa* *Kinneyia simulans* *Greysonia basaltica* *Copperia tubiformis*
Chamberlain shales	1,500	
Neihart sandstone	700	
	12,000	

Unconformity

Archean complex

[1] Bull. Geol. Soc. America, Vol. 10; 1899, pp. 201-215.

The fauna of the Greyson shales occurs toward the base of the formation. *Collenia undosa* is found at many horizons in the Spokane shales, and the Newland limestone algæ are reported by Mr. M. Collen to occur throughout the section of that formation on the eastern slope of the Big Belt Mountains.

THE ALGAL FLORA

The algal flora of the Algonkian and the *Cryptozoon*-like species from the Cambrian and later formations are now considered to have been deposited through the agency of algæ similar in type and activity to the (Cyanophyceæ) Blue-green Algæ. No traces have been seen of the fine stems of the algæ but single cells and strings of cells have been found with a magnification of 260 diameters.

In the fresh-water lakes of the present time the Blue-green algæ form a thin felt-like layer over some object either minute or large as the case may be. As the under side of this layer dies the outer surface sends the delicate slender stems out into the water until these in turn become twisted and matted together and added to the inner layer. If there is bicarbonate of lime or magnesia in the water a portion is taken up by the algæ and deposited in the laboratory existing in the matted portion of the inner layer and added to the thin layer of calcareous matter. The result is shown in sections of " Lake Balls " illustrated by the figures on plate 4. Some genera and species of the algæ build up concentric forms like those shown on plate 4, while others build up sponge-like masses that form solid beds along the shore or in shallow portions of the lake (pl. 4, fig. 4).

The examination of a large series of the Algonkian and Cambrian algæ illustrated in this paper fails to disclose any traces of internal structure (except miroscopic cells) such as occurs in most of the marine algæ (Corallinaceæ, Characea, etc.), but nearly all have a distinct structure resulting from the deposition of calcium carbonate in certain definite forms. This may be the simple concentric lamination of *Collenia* (pl. 13), the more complicated *Newlandia* (pl. 6), or the elongate cellular pipe-like *Greysonia* (pl. 17).

Comparison of recent Blue-green algæ deposits and those of Algonkian time.—On comparing the sections of the " Water Biscuit " (pl. 4) with sections of *Collenia* (pl. 13) from the Spokane shales of the Belt series of Montana, a striking similarity in their structure is seen. Both are formed of concentric laminations without any apparent structural connection between them as the interspaces are filled in with irregular granulations without any particular method of arrangement.

The mode of growth of the recent and ancient forms has many points in common. The "Water Biscuit" are found on the muddy or sandy lake-bottom; in some places quite abundant and in others more scattered. The specimens of *Collenia* from the Spokane shales occur embedded in a very fine arenaceous shale, sometimes in great numbers. That they were formed on the muddy bottom of a body of water which was shallow, is shown by the presence of ripple marks and sun cracks at various horizons in the shales. The specimens of *Collenia* vary in size from the size of a mustard seed up to a foot or more in diameter, and usually occur with the flattened or hollow side downward. They may be scattered about singly or in groups or attached to each other so as to form a mass of calcareous nodules.

There is considerable siliceous matter occurring in the laminations of *Collenia* and also dolomitic partings between the laminations of growth although all openings in the original specimen are now filled with a dark bluish-gray limestone.

Another case of resemblance between a deposit made by Blue-green algæ and the Algonkian fossil algæ is seen by comparing a section of a fragment of a large deposit in a fresh-water lake in Michigan (pl. 4, fig. 4) with a section from the Belt terrane that I have named *Camasia spongiosa* (pl. 12).

From the fact that the recent laminated lake balls and layer deposits were largely deposited through the agency of Blue-green algæ, it is probable that the same simple types of algæ were the active agents in depositing the forms described in this paper under the generic names of *Collenia, Newlandia, Camasia, Kinneyia, Weedia, Greysonia,* and *Copperia*. The finding of single cells and chains of cells with *Camasia spongiosa* is a most important factor in establishing the presence of the (Cyanophyceæ) Blue-green algæ-like forms in connection with the Algonkian forms listed above.

Mode of growth.—In the absence of sticks of wood, stones and other solid objects upon which to start their growth, as do the modern Blue-green algæ, the Algonkian forms evidently started and built up their structures on bits of hardened mud and often on fragments of algal deposit broken up by current or wave action. Most of the forms spread out along the surface of the muddy bottom until they were buried beneath an influx of ooze or mud that filled all the cavities and channels in the algal deposits. In the Newland limestone specimens the filler was a fine calcareous mud, and in those from the Spokane shale an argillaceous mud. One of

the undecided questions is the stopping of growth at the top of each layer of limestone. Why some of the stronger forms did not extend above the level top surface of the layer in which they are found, it is difficult to conjecture. It may be that a strong current swept away the smaller pieces and filled in the interspaces among the larger forms. It is planned to give attention during the field season of 1914 to the occurrence of the large masses in the Newland limestone with special reference to their mode of growth.

Mineral composition.—A compact specimen of *Camasia spongiosa* with very small opening into which the calcareous mud could penetrate gave the following result as determined by Dr. Edgar T. Wherry of the United States National Museum:

Oxides	
CaO	40.52
MgO	1.15
$CO_2 + H_2O$	33.38
$Fe_2O_3 + Al_2O_3$	3.72
SiO_2	21.08
	99.85

An analysis of a second specimen from which the calcareous matter deposited within the cellular openings had been removed by solution in hydrochloric acid gave the following:

Oxides	
CaO	10.88
MgO	0.27
$CO_2 + H_2O$	10.20
$Fe_2O_3 + Al_2O_3$	10.22
SiO_2	68.32
	99.89

The second analysis may be taken as indicating the present mineral composition of the deposit made by the algæ. What its original composition was cannot well be determined as there has evidently been a large replacement by silica unless there was some unrecognized siliceous sponge associated with it that furnished the silicia.

Microscopic structure.—Being fairly well convinced from the comparison of "Lake Balls" and other recent massive calcareous

fresh water deposits with *Newlandia*, *Camasia*, *Collenia* and *Cryptozoon*, that water plants similar to the Blue-green algæ were the agents that built up the fossil algal flora of the Algonkian, I asked my friend Dr. Albert Mann, the microscopist, if he would not study thin sections of the rock in which the specimens occur, also the residual mud resulting from the dissolving of the algal limestone by hydrochloric acid. He very kindly consented, and soon found in the residual material many single cells and groups of cells such as occur in the recent Chroococcaceæ (pl. 20, fig. 5) and rows of cells similar to those of the recent Nostocaceæ.

A row or chain of cells derived from *Camasia spongiosa* is shown by figures 2-4, plate 20. Figure 4 is from an untouched photograph (x 350). Owing to the chain or filament not being in the same plane from end to end many of the cells are not in focus in figure 4. In order to correct this the entire series of cells have been outlined in figure 2, and in figure 3 this is further enlarged so as to show the outline of the cells. The same conditions exist in a chain of cells in a filament of a recent Blue-green alga, *Schizothrix*, from the surface of a calcareous deposit in Green Lake, New York. Figure 8 is from an untouched photograph, and figure 8*a* shows the full length of the chain. The chain represented by figures 2-4 is embedded in a very thin plate of opal-like silica.

Figure 5 represents a cluster of round cells (x 350) with their outline strengthened, and figure 5*a* as they appear in the untouched photograph. A group of longitudinally arranged cells is shown by figure 6*a*, and in the untouched photograph represented by figure 6. A group or chain of cells of a recent, calcareous depositing Blue-green alga is shown by figure 7 (x 1,200). This may be compared with figure 3 from *Camasia spongiosa* of the Newland limestone.

A number of very thin opal-like siliceous plates show minute tubes such as are illustrated by figure 1. These appear to be of organic origin and may represent minute tubes similar to those found in some genera of Blue-green algæ.

Bacteria.—Although the existence of Bacteria in Algonkian time has not been demonstrated from the observations already given (pp. 92-94); it is quite probable that the Bacteria were a most important factor in the deposition of the Algonkian limestones.

Classification.—For the purpose of grouping the various forms of the algal flora of the Algonkian the following classification is made from external form.

Massive—Cellular—*Camasia spongiosa*

Semisphærical	*Cryptozoon* and its allies *? Newlandia concentrica* *Weedia tuberosa* *Collenia undosa* *Collenia compacta*
Flabelliform	*Newlandia frondosa* *Newlandia lamellosa* *Newlandia major* *Kinneyia simulans*
Tubiform	*Greysonia basaltica* *Copperia tubiformis*

All of the genera and species are based on the variation in form, as it is impossible with the data now available to determine the genera or species of the Cyanophyceæ that built up the widely differing forms described in this paper. They all agree in not having the structure of the higher algæ, Corallinaceæ, etc. All appear to have been deposited as successive layers, the inner and older layers serving as a foundation on which the younger filaments grew in variously arranged forms. In the absence of the identification of the actual algæ that built up the structure found in the fossil state, a purely artificial classification has been adopted that includes a number of new generic and specific names as given above.

DESCRIPTION OF GENERA AND SPECIES

NEWLANDIA, new genus

More or less irregular semispherical or frondlike forms built up of concentric, subparallel, subequidistant thin layers that may be connected by very irregular, broken partitions.

Genotype.—Newlandia frondosa, new species.

Stratigraphic range.—Lower portion of Newland limestone.

Geographic distribution.—Eastern slope of Big Belt Mountains, Montana.

Observations.—The compact, semispherical forms of *Newlandia* have regular concentric laminations that recall the laminated structure of some forms of *Collenia* and *Cryptozoon.* They differ in having more regular and broader interspaces devoid of the fine laminations so characteristic of *Cryptozoon.* It is not improbable that *Newlandia concentrica* (pl. 5, figs. 2, 3) may ultimately be found to be identical with the concentric forms of *N. frondosa* (pl. 5, fig. 4; pl. 6, figs. 1, 2; pl. 7), but with the specimens now available for

study the semispherical forms are considered as representing a distinct species. *Newlandia frondosa* (pl. 6) illustrates both the laminated and coarsely cellular form of growth. Some of its fronds are two feet (60 cm.) or more in diameter with a thickness of 4 inches (10 cm.) or more.

The species referred to *Newlandia* are:

Newlandia concentrica Walcott (pl. 5, figs. 2, 3)
Newlandia frondosa Walcott (pl. 5, fig. 4; pls. 6-8)
Newlandia lamellosa Walcott (pl. 10, figs. 1, 2)
Newlandia major Walcott (pl. 9, fig. 3)

NEWLANDIA CONCENTRICA, new species

Plate 5, figs. 2, 3

Semisphærical bodies, built up of concentric layers of irregular thickness that appear to be attached at the base of each cup-shaped concentric layer, and also by irregular projections from the surface of the layers. The layers are perforated to a greater or less extent by irregularly shaped and located small openings. The thickness of the layers varies from 0.5 cm. or less to 2 or 3 mm. The largest individual specimen has a transverse diameter of 9 cm. with a depth of 1.5 cm. A smaller specimen has a depth of 3 cm. These measurements are not very important as the specimens have evidently been somewhat crushed down.

Observations.—The concentric form of growth of this species is much like the concentrically arranged layers of the nucleus of some of the specimens of *N. frondosa*. It differs in having interspaces between the layers and in its more regular form.

The growth appears to have been about a nucleus around the base of which successive layers were built up. It is anticipated that future collections will afford the material for a more detailed description.

Formation and Locality.—(400c) Algonkian, Beltian series; Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

NEWLANDIA FRONDOSA, new species

Plate 5, fig. 4; plate 6, figs. 1-3; plate 7, figs. 1, 2; plate 8, figs. 1-3

Large frond-like forms built up of thin layers that may have a laminated arrangement (pl. 7) or a combined coarse cellular and laminated structure (pl. 6). The large fronds appear to have

started from a central section and increased in size by the addition of thin layers that are more or less parallel to each other. The number of layers may also increase by intercalating layers that are attached at their points of origin to one of the adjoining layers. The lower side of the frond-like forms usually has an irregular skin-like layer that served as a base for the coarse, sponge-like and laminated growth above. The additions to the base and to the body above were made in more or less irregular, concentric lines. An imperfect series of connecting radial structure is shown by figs. 1 and 2, plate 7, and fig. 1, plate 8.

How the various forms grew by accretion and why their upward growth was limited is discussed in the introduction under Mode of Growth (p. 101).

Specimens of this form attain a large size. Some in the collection indicate a diameter for the entire body of from 2 to 3 feet (60 to 80 cm.) with a thickness of 4 inches (10 cm.) or more.

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

NEWLANDIA LAMELLOSA, new species

Plate 10, figs. 1, 2

Layers forming the body and interspaces much narrower and more regular than those of *N. frondosa.* The form of growth in flat, frond-like bodies was much like that of *N. frondosa.* The largest fragment in the collection has a length of 23 cm. and a thickness of 3.5 cm.

This form differs from *Kinneyia simulans* in the greater regularity of its layers, and from other species of *Newlandia* by the fine, closely arranged layers.

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

NEWLANDIA MAJOR, new species

Plate 9, fig. 3

This species is founded on a fragment of a large frond-like body. It has a length of 27 cm. and a depth of 8 cm. The layers forming the body are very thin and separated by interspaces much wider

than in other species. The two fragments known indicate a greater diameter and thickness than for any other species of the genus.

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

KINNEYIA, new genus

Body built up of thin, subparallel layers separated by narrow intervals that are not much greater than the thickness of the layers forming the body.

This form differs from *Newlandia* in its finely laminated arrangement of its layers and interspaces and the marked bifurcation of the layers forming the body.

Genotype.—*Kinneyia simulans,* new species.

As far as known the geographic distribution and the stratigraphic range are the same as for *Newlandia.*

KINNEYIA SIMULANS, new species

Plate 11, fig. 3

There are several specimens of this species that have the characters shown by fig. 3, of plate 11, which is the upper etched surface of a block 22 mm. in thickness down through which the layers forming the body extend almost vertically. The layers of some of the specimens are a little coarser than those represented by fig. 3, plate 11, but they have the same character.

The mode of growth was probably much like that of *Newlandia frondosa.*

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Mountains, at forks of Birch Creek, Meagher County, Montana.

WEEDIA, new genus

Irregular, encrusting, and solid deposits that gathered as tubercles, ridges, and many irregular forms on the bed of the body of water in which the algæ forming them lived. The specimens suggest a secondary siliceous deposit in the limestones, but the concentric laminated structure of the tubercles points more strongly to an origin similar to that of the encrustations made through the agency of the Blue-green algæ (Cyanophyceæ).

Genotype.—*Weedia tuberosa,* new species.

Stratigraphic range.—Upper part of the Altyn limestone series interbedded with siliceous and cherty layers.

Geographic distribution.—Above Gunsight Pass, Glacier National Park, Montana. This will probably be found to be a widely distributed form in the Algonkian formations. Heretofore such forms have been passed over as of concretionary origin or as of secondary siliceous deposits.

Observations.—The generic name is given in recognition of the work of Dr. Walter H. Weed among the Algonkian formations of the Belt Mountains of Montana.

WEEDIA TUBEROSA, new species

Plate 11, figs. 1, 2

The external characters of this species are well shown by figure 2, plate 11. Also the structure of the tubercles as they have been cut into by erosion so as to expose the irregular laminations and in figure 1 the hollow interior, a feature so often seen in recent "Lake Balls," plate 4. The main portion of the specimens represented by figure 2 is a thin encrustation on the upper surface of a layer of limestone.

Formation and locality.—(400) Algonkian: Siyeh limestone; above Lake McDonald, south side of Gunsight Pass, Glacial National Park, Montana.

GREYSONIA, new genus

Irregular, cylindrical or tubular growth with relatively thin walls except at the union of three or more tubes, where the walls are thickened as shown by figure 2, plate 17, and figure 1, plate 18. The tubes are large, irregularly rhomboidal or pentagonal in section with the interior now filled in with a dark bluish-grey limestone. The walls or partitions represent the deposit made by the algæ and are now a buff-colored and grey magnesian limestone.

The ends of a group of the tubes filled in with the limestone appear like a group of miniature basaltic columns (pl. 17, fig. 2), and the base or lower side of the same tubes has irregularly oval and round, concentrically marked forms that appear to be the filling of the ends of the tubes. The walls of the tubes surrounding the ovals and the basal ends are shown by figure 2, plate 18, and the broken upper ends by figure 2, plate 17. The walls are arranged in echelon and the fillings break out as plates of columns (fig. 1, pl. 17).

Mode of growth.—As far as indicated by the specimens collected by Mr. M. Collen the cellular structure grew with the tubes more or less parallel to the bottom and in some instances upright or at right angles to the bottom. The section illustrated by figure 1, plate 18, shows that it was formed of four rows of tubes parallel to the under and upper surface of the layer of limestone. The specimen represented in part by figure 2, plate 17, and figure 1, plate 18, is 36 cm. in length, with a depth of 18 cm. It has 12 rows of tubes, and it is evidently part of a much larger mass. The tubes vary from 1 to 2 cm. in diameter.

Genotype.—*Greysonia basaltica*, new species.

Stratigraphic range.—Lower portion of Newland limestone.

Geographic distribution.—Eastern slope of Big Belt Mountains, Montana.

Observations.—It is difficult to conceive of the tubular structure of *Greysonia* as a deposit made by algæ, but with the example of the varied forms of recent deposits made by the Blue-green algæ (Cyanophyceæ) and the other fossil forms described in this paper we are prepared to consider *Greysonia* as of algal origin. There is evidently much yet to be learned of its mode of growth, but that is a matter of further field study.

GREYSONIA BASALTICA, new species

Plate 17, figs. 1, 2; plate 18, figs. 1, 2

The generic description contains what is known of this species from the material now in the collection.

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

COPPERIA, new genus

A tubular structure formed of thin partition walls that are thickened at the junction of three or more tubes. The tubes are in echelon arrangement and break out in plates as shown by figure 2, plate 19.

In the specimen illustrated by figure 3, plate 19, the four lower layers of tubes were formed in a horizontal position and above them the growth was irregular, the tubes curving and also bending up to the surface of the layer.

The tubes are nearly circular in outline and probably grew in a large frond on the bed of the body of water in which the algæ lived. The tubes are now filled with dark greyish-blue limestone.

Genotype.—*Copperia tubiformis,* new species.

Stratigraphic range.—Lower portion of Newland limestone

Geographic distribution.—Eastern slope of Big Belt Mountains, Montana.

Observations.—At first I was inclined to place this form under *Greysonia,* but from the form of the tubes and the irregular habit of growth concluded to give it a distinct generic designation.

COPPERIA TUBIFORMIS, new species

Plate 19, figs. 1-3

The principal characters of the species are given under the generic description. The largest fragment in the collection has a length of 15 cm. The tubes are from 7 to 10 mm. in diameter and the thickness of the layer made up of layers of the tubes is 6 cm.

Formation and locality.—(400c) Algonkian, Beltian series: Newland limestone; eastern slope of Big Belt Mountains, 8 miles (12.8 km.) west of White Sulphur Springs, at forks of Birch Creek, Meagher County, Montana.

COLLENIA, new genus

More or less irregular dome-shaped, turbinate or massive, laminated bodies that grew with the arched surface uppermost. The growth appears to have been by the addition of external layers or lamellæ of varying thickness with interspaces that vary greatly even in the same specimen.

Genotype.—*Collenia undosa,* new species.

Stratigraphic range.—The type species occurs in the Spokane shales of the Big Belt series of Montana.

Collenia compacta, new species, is from the Siyeh limestone and several thousand feet above the horizon of *Collenia undosa.*

Collenia occidentale (Dawson) is from the Chuar terrane of the Grand Canyon, where it ranges through 1,500 feet (460 m.) of strata.

Geographic distribution.—Eastern slope of the Big Belt Mountains, south of White Sulphur Springs, Meagher County, Montana. Gunsight Pass, Glacial National Park, Montana. Chuar Valley in the Grand Canyon, Arizona.

Observations.—The resemblance between the structure of *Collenia* and *Cryptozoon* Hall[1] is marked in hand specimens as may be seen by comparing illustrations of the two forms. Both have a laminated appearance in sections, the concentric lamellæ varying in thickness and in the width of their interspaces, but when we compare the mode of growth we find that *Collenia* has an encrusting-like growth that forms a dome-shaped body with the edges of the lamellæ pointing downward (pl. 13, fig. 1), while *Cryptozoon* grows in a cup-shaped form with the edges of the lamellæ on the upper surface (pl. 16).

Specimens of *Collenia* are usually small, although they attain a diameter of 12 inches (32.7 cm.) or more.

The *Collenia*-like turbinate form that I found in the Algonkian series of the Grand Canyon in 1882, and sent to Sir William Dawson in 1897, had the same manner of growth as *Collenia undosa* except that owing to its being crowded together it grew to a greater height from a narrow base (pl. 15, figs. 5, 6).

Collenia compacta (pl. 15, fig. 7) grew in part like *C. occidentale,* but it also developed a laminated growth that filled the interspaces between the more individual club-shaped forms.

The species now referred to *Collenia* from the Algonkian group are:

Collenia compacta Walcott (pl. 15, fig. 7)
Collenia ? frequens (Walcott)[2] (pl. 10, fig. 3)
Collenia occidentale (Dawson) (pl. 15, figs. 1-6)
Collenia undosa Walcott (pl. 13, figs. 1, 2; pl. 14, figs. 1, 2)
Collenia ? sp. undt.

Dr. J. G. Bornemann described under the name *Zonatrichites* an algal form from the Mesozoic rocks as follows:[3]

A calcareous alga, with radially arranged filaments, forming hemispherical or kidney-shaped layers, growing on or enclosing other bodies. Parallel or concentric zones are seen in cross-section, formed by the periodic growth of the alga, the older and dead layers serving as a foundation on which the young filaments grow in radially arranged groups.

Mr. A. C. Seward comments upon the form as follows:[4]

The nodules which are apparently formed by species of this genus occur in various sizes and shapes; Bornemann describes one hemispherical mass 8

[1] Thirty-second Ann. Rept., New York State Mus., Nat. Hist., 1883, Description of pl. 6.

[2] Bull. Geol. Soc. America, Vol. 17, 1906, pl. 11.

[3] Geologische Algenstudien, Jahrb. k. preuss. geol. Landesanst. Berkakad., 1886, p. 126, pls. 5 and 6.

[4] Fossil Plant, Cambridge Press, Vol. 1, 1898, pp. 129, 130.

cm. broad and 4 cm. thick. In some cases the organism has given rise to oölitic spherules, which in radial section exhibit the branched tubular cells spreading in fan-shaped groups from the centre of the oölitic grain. The section parallel to the surface of a nodule presents the appearance of a number of circular or elliptical tubes cut across transversely or more or less obliquely. The resemblance between the fossil and a specimen of the recent species *Zonatrichia calcivora* Braun, is certainly very close, but it is very difficult, in the absence of material exhibiting more detailed structure than is shown in the specimens described by Bornemann, to decide with any certainty the true position of the fossil. The figures do not enable us to recognize any trace of cells in the radiating tubes. It is possible that we have in *Zonatrichites* an example of a Cyanophyceous genus in which only the sheaths of the filaments have been preserved. In any case it is probable that this Mesozoic species affords another instance of a fossil alga which has been responsible for certain oölitic or other structures in limestone rocks.

I refer to *Zonatrichites* as in external form and section it closely resembles *Collenia*.

Dr. A. C. Peale, in describing the limestones of the lower part of the Algonkian section as exposed at the south end of the Madison Range, Montana, on the south side of the Gallatin Valley, mentions the occurrence of so-called concretions that had been mistaken for fossil turtles by the people living in the region.[1] He describes the concretions as very large, often measuring several feet in diameter and from 6 to 12 inches (15 to 30 cm.) in thickness, averaging about 6 inches to a foot in diameter, with a thickness of only 3 to 4 inches (7.5 to 10 cm.).

The above description strongly suggests that the so-called concretions are a form of *Collenia,* or possibly *Cryptozoon.* It is anticipated that the locality will be visited, and study made of their occurrence and character, during the season of 1914 (pp. 116-117).

COLLENIA COMPACTA, new species

Plate 15, fig. 7

This species has a turbinate growth, also in the solid layers of limestone a massive laminated growth that is irregular and compact. The two forms of growth are well shown by plate 15, figure 7. The finer lamellæ occur in bands outlined by coarser lamellæ.

Where the specimens in the collection were found they occurred in a layer 9 cm. thick. The layer appeared to be made up of the turbinate forms and intervening laminations and broken fragments.

[1] Bull. U. S. Geol. Survey, No. 110, 1893, p. 17.

Formation and locality.—Algonkian: (400a) Siyeh limestone; Continental Divide at head of Kipps Creek, a branch of Mineral Creek, east of Flat-top Mountain, Glacial National Park, Montana (C. D. Walcott, 1908).

COLLENIA ? FREQUENS (Walcott)

Plate 10, fig. 3

Cryptozoan frequens Walcott, 1906, Bull. Geol. Soc. America, Vol. 17, pl. 11. (Species figured.)

This form has an upright, irregular cylindrical growth, that appears like paving blocks fitted closely together. The individual bodies vary from 2 inches (5 cm.) in diameter up to 15 inches (38 cm.) or more. In the great limestone block illustrated the depth of the cylindrical growth is about 16 inches (43 cm.).

I hope to obtain during the season of 1914 much more information about this form.

Formation and locality.—Algonkian: Siyeh limestone; Little Kootna Creek, Chief Mountain quadrangle, Montana.

COLLENIA UNDOSA, new species

Plate 13, figs. 1, 2; plate 14, figs. 1, 2

More or less irregularly dome-shaped, semisphæroidal, sometimes roughly sphæroidal, laminated bodies that are usually roughly concavo-convex. They appear very much as though the under side had been dug out or that the first encrusting calcareous deposit was made over a lump of mud. The interior of the body is made up of alternating fine and coarse laminations subparallel to the upper and lower surfaces of the body.

Individual specimens occur scattered in reddish silico-argillaceous shale and sometimes in groups of irregular forms as shown by figures 1 and 2, plate 14. In some instances thin layers of somewhat siliceous or magnesian limestone are nearly filled with broken and more or less entire specimens, as shown by figure 1 on plate 13. In sections of the roughly sphæroidal forms it appears as though a high dome-shaped specimen had been rolled over during growth and a new growth started that covered the hollow under side so as to enclose fragments of other specimens in the interior of the mass (pl. 13, fig. 2).

The outer surface is often botryoidal as indicated by the structure in the upper part of the section illustrated by figure 2, plate 13. The greater number of specimens are from 3 to 4 inches (7.6

to 10 cm.) in diameter, but some are a foot (32.7 cm.) or more across.

Formation and locality.—Algonkian: (400b) Beltian series; Spokane shales; 8 miles (12.8 km.) west of White Sulphur Springs at forks of Birch Creek, Meagher County, Montana (M. Collen, 1906).

COLLENIA ? species undetermined

The late Professor N. H. Winchell recently sent me, a few days before his death, photographs of a specimen that suggests *Collenia*. It is made up of 28 vertical columnar bodies which show on the top a roughly hexagonal section. Their average size is about 1 cm. The columns are made up of concentric lamellæ, somewhat like those of *Atikokania* from the Steeprock series in Canada.

I have not seen the specimen nor is its origin known. It was found in a ballast gravel of the railroad that came from glacial drift, near St. Paul, Minnesota.

ARCHÆOZOAN ACADIENSE Matthew

Archæozoan acadiense Matthew, 1901, Bull. Nat. Hist. Soc., New Brunswick, No. 9, Presidential Address, p. 32; also pp. 38-41.

Dr. G. F. Matthew describes a "reef of limestone" of pre-Cambrian age containing numerous fragments of a concretionary structure which he regarded as of organic origin. He says:[1]

> The reef began its growth on a bottom of fine sand, now converted into a quartzite rock which forms an important member of the Upper Series. There the objects consist of a multitude of small, short, closely-set columns, which grew tier upon tier, with, at first, more or less of sand between the tiers.
>
> It may be observed also that these crowded clusters of columns were often cut off over considerable areas, by thin horizontal layers of mineral matter, perhaps indicative of the incursion of sand or other sediment, but the growth was almost immediately renewed by a new set of columns, occupying the fresh surface of mud that covered the old ones. . . . .
>
> This reef of calcareous columns was about one hundred and fifty feet deep. . . . .

He compares these forms with *Eozoan canadense*. The mode of growth also suggests *Collenia occidentale* and *C. compacta*. I hope to have specimens for study in the fall of 1914 that will possibly determine the origin of these problematical fossils. My present impression is that they are of algal origin.

Formation and locality.—"Laurentian" limestone: St. John River, near St. John, New Brunswick.

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[1] Bull. Nat. Hist. Soc., New Brunswick, No. 9, 1901, pp. 38, 39.

CAMASIA, new genus

Compact layer-like growth with numerous irregular tube-like openings that give a spongoid appearance in cross sections of the tubes (pl. 12, figs. 1 and 2). The openings or tubes are smallest at the base, increasing inside toward the summit of the layer. In the specimen illustrated by figure 2, plate 9, they are very small and all are inclined in one general direction. In another large specimen (pl. 12, fig. 2) the irregular tubes and openings extend obliquely to the left about one-third of the way and then very irregularly in an oblique direction to the right to near the top of the layer.

A row or chain of cells derived from *Camasia spongiosa* is shown by figures 2-4, plate 20, and a cluster of round cells by figure 5. These cells are of essentially the same character as those found in the filaments of the recent Blue-green Algæ.

Genotype.—*Camasia spongiosa,* new species.

Stratigraphic range.—Lower portion of Newland limestone.

Geographic distribution.—Eastern slope of Big Belt Mountains, Montana.

Observations.—As far as now known this species is represented by one species that forms layers varying in thickness and extent. The largest specimen in the collection has a thickness of 7 cm., with a length of 21 cm. It is apparently a fragment of a large mass that extended over a much larger area.

The microscopic cells illustrated on plate 20 were obtained by treating the specimen with hydrochloric acid and examining the residual matter. All of the chains of cells thus far seen occur in thin opal-like plates such as are found abundantly in the recent calcareous lake deposits formed by Blue-green Algæ.

The only species yet referred to the genus is *Camasia spongiosa.*

CAMASIA SPONGIOSA, new species

Plate 9, figs. 1, 2; plate 12, figs. 1, 2; plate 20, figs. 2-6, 6*a*

The general form of this species is shown by the illustrations on plates 9 and 12. It resembles in some respects the recent growth deposited by Blue-green Algæ as represented by figure 4 on plate 4.

It evidently grew in extended masses on the bottom. The few specimens in the collection are only fragments, and none of them show indications of having come from near the outer margin of the mass of which they formed a part.

The microscopic structure is referred to on page 103 and illustrated on plate 20, figures 2-6.

An attempt will be made during the field season of 1914 to discover the mode of growth and the extent of this species. It is unusually interesting owing to its resemblance to the deposit made by the Blue-green Algæ in the fresh-water lakes of New York, Michigan, and elsewhere.

Formation and locality.—Algonkian: (400c) Beltian series: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs at forks of Birch Creek, Meagher County, Montana (M. Collen, 1906.)

GALLATINIA, new genus

As there is but one species of the genus known the generic and specific description is united for the present in the description of the species.

Genotype.—Gallatinia pertexa, new species.

Stratigraphic range.—As far as known it is limited to a few layers of limestone in the central portion of the Algonkian section of the Gallatin Valley.

Geographic distribution.—North side of Gallatin and East Gallatin Rivers, between Gallatin Station and Dry Creek, Gallatin County, Montana.

GALLATINIA PERTEXA, new species

Plate 23, figs. 1, 2

External form discoid, circular, flattened. In a specimen 21 cm. in diameter there is an outer border about 3 cm. in width and 4 cm. in depth that extends from the base to the upper surface of the specimen. This outer ring is united to the center by seven ray-like arms arranged in a more or less irregular manner. The outer border ring is formed of fine, irregular lamellæ that slope inward more or less from the base to the upper surface. The radiating arms are formed of a series of V-shaped lamellæ that extend down into the mass of the specimen a distance equal to about their width at their upper surface. The border ring and arms are connected by a mass of vesicular lamellæ that fill the interior of the specimen. At the upper surface between the radiating arms the vesicular lamellæ form more or less concentric lines about the center.

The photographs of the specimen show the details of structure fairly well.

The specimen is formed of a siliceous, buff-weathering material with a filling in all interspaces of dark, bluish-gray limestone that is readily removed in solution by weak hydrochloric acid.

Observations.—Recently when reading an account by Dr. A. C. Peale of the pre-Cambrian rocks of the region between the Missouri River and Dry Creek, a tributary of the East Gallatin River, Gallatin County, Montana, I noted that he described the occurrence of numerous flattened concretions in an Algonkian limestone[1] which the people in the vicinity called fossil turtles. On inquiring of Dr. Peale he told me that there was a specimen in the United States National Museum. Upon examining it there was very little to indicate that it was more than an ordinary septaria-like concretion. Cutting a cross section on one side and treating it with acid the wonderful interior and exterior structure was developed that is shown in the accompanying illustrations. Dr. Peale states that the "concretions" measure several feet in diameter and from 6 to 12 inches (15.4 to 31 cm.) in thickness, and that they occur in a limestone.

An examination of the residual sediment resulting from dissolving some of the limestone matrix shows microscopic cells much like those found with *Cryptozoon* and *Collenia*.

I anticipate visiting the locality where Dr. Peale collected the specimen described and hope to be able to give a much fuller account of the occurrence and character of this remarkable addition to the Algonkian algal flora.

Formation and locality.—Algonkian: (400j) Belt terrane; north side of Gallatin and East Gallatin Rivers, north of Bartons Bridge, west of Hillsdale Postoffice, Gallatin County, Montana (A. C. Peale, 1885).

After this paper was in page proof I received from Dr. G. R. Wieland a copy of his paper on "Further Notes on Ozarkian Seaweeds and Oölites"[2] in which he discusses the various forms that have been referred to *Cryptozoon*. This important contribution to the subject of fossil algæ will be referred to in any future study I may make of the pre-Cambrian fossil algæ.

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[1] Bull. U. S. Geol. Survey, No. 110, 1893, p. 17.

[2] Bull. American Museum Nat. Hist., Vol. 33, pp. 237-260.

DESCRIPTION OF PLATE 4

PAGE

Lake Balls formed by Blue-green algæ. (See pl. 5) 100

FIG. 1. (× 2.) Exterior surface of pear-shaped specimen. U. S. National Museum, Catalogue No. 60690.

2. (× 2.) Transverse section of an ovel-shaped ball, showing concentrically laminated structure. U. S. National Museum Catalogue No. 60691.

These lake balls were in the process of formation by filamentous algæ when taken from the lake.

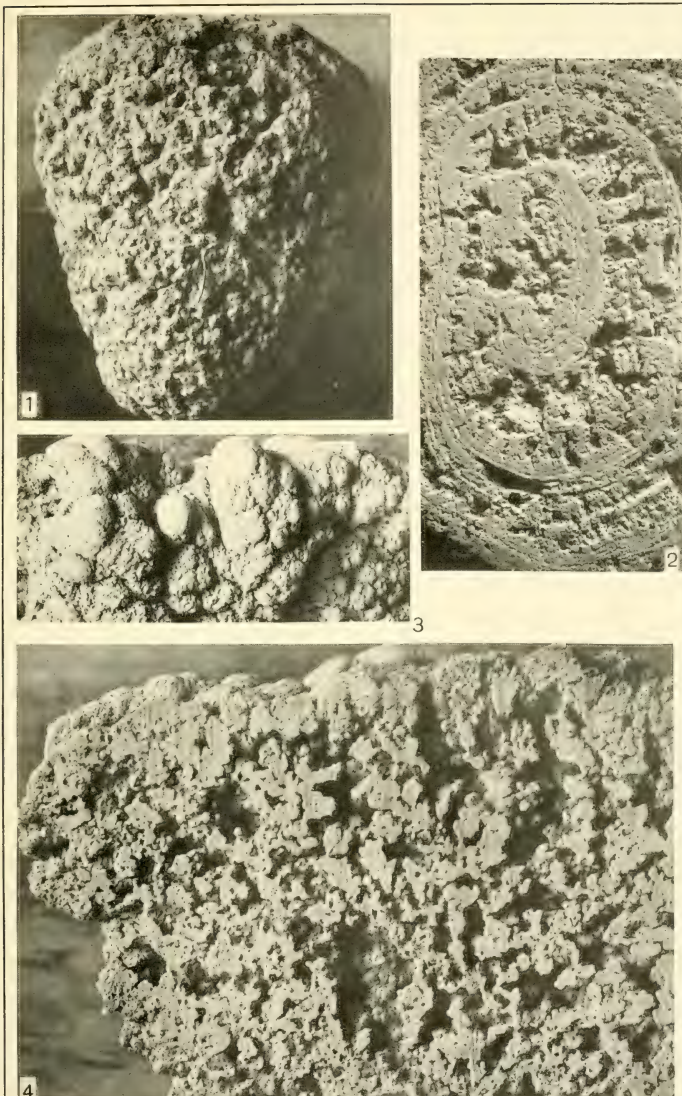
Locality: Squaw Island, Canandaigua Lake, New York.

Layer deposit by Blue-green algæ 100

FIG. 3. (Natural size.) Botryoidal outer surface of specimen represented in section by figure 4. The same occurs in *Collenia undosa* (pl. 13, fig. 2). U. S. National Museum, Catalogue No. 60692.

4. (Natural size.) Vertical section through a layer 7.5 cm. thick. Compare with the section of *Camasia spongiosa* (pl. 12, fig. 1). U. S. National Museum, Catalogue No. 60692.

The specimen illustrated by figs. 3 and 4 is from Green Lake, 2 miles (3.2 km.) southwest of Kirkville, Onondaga County, New York.



LAKE BALLS AND LAYERS, FORMED BY RECENT BLUE-GREEN ALGÆ

DESCRIPTION OF PLATE 5

PAGE

Section of *Lake Ball* formed by Blue-green algæ. (See pl. 4) 100

FIG. 1. ($\times$ 4.) Transverse section of an elongated ball, showing laminated structure and the presence of several nuclei toward the center of the section. U. S. National Museum, Catalogue No. 60693.

Locality Squaw Island, Canandaigua Lake, N. Y.

Newlandia concentrica Walcott 105

FIG. 2. (Natural size.) View of upper portion of concentrically arranged laminations as exposed by natural weathering, U. S. National Museum, Catalogue No. 60694.

3. (Natural size.) Upper surface showing concentric laminations exposed by the removing of the limestone by acid. U. S. National Museum, Catalogue No. 60695.

Newlandia frondosa Walcott (See pls. 6-8) 105

FIG. 4. (Natural size.) This specimen illustrates a concentric structure toward the center with laminations to the right and left that are cut off at top and bottom by the surface of the layer of limestone in which they occur. U. S. National Museum, Catalogue No. 60696.

The specimens represented by figs. 2-4 are from locality 400c: Algonkian; Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.

1. LAKE BALL

2, 3. NEWLANDIA CONCENTRICA Walcott

4. NEWLANDIA FRONDOSA Walcott

DESCRIPTION OF PLATE 6

PAGE

Newlandia frondosa Walcott. (See pls. 5, 7, 8) 105

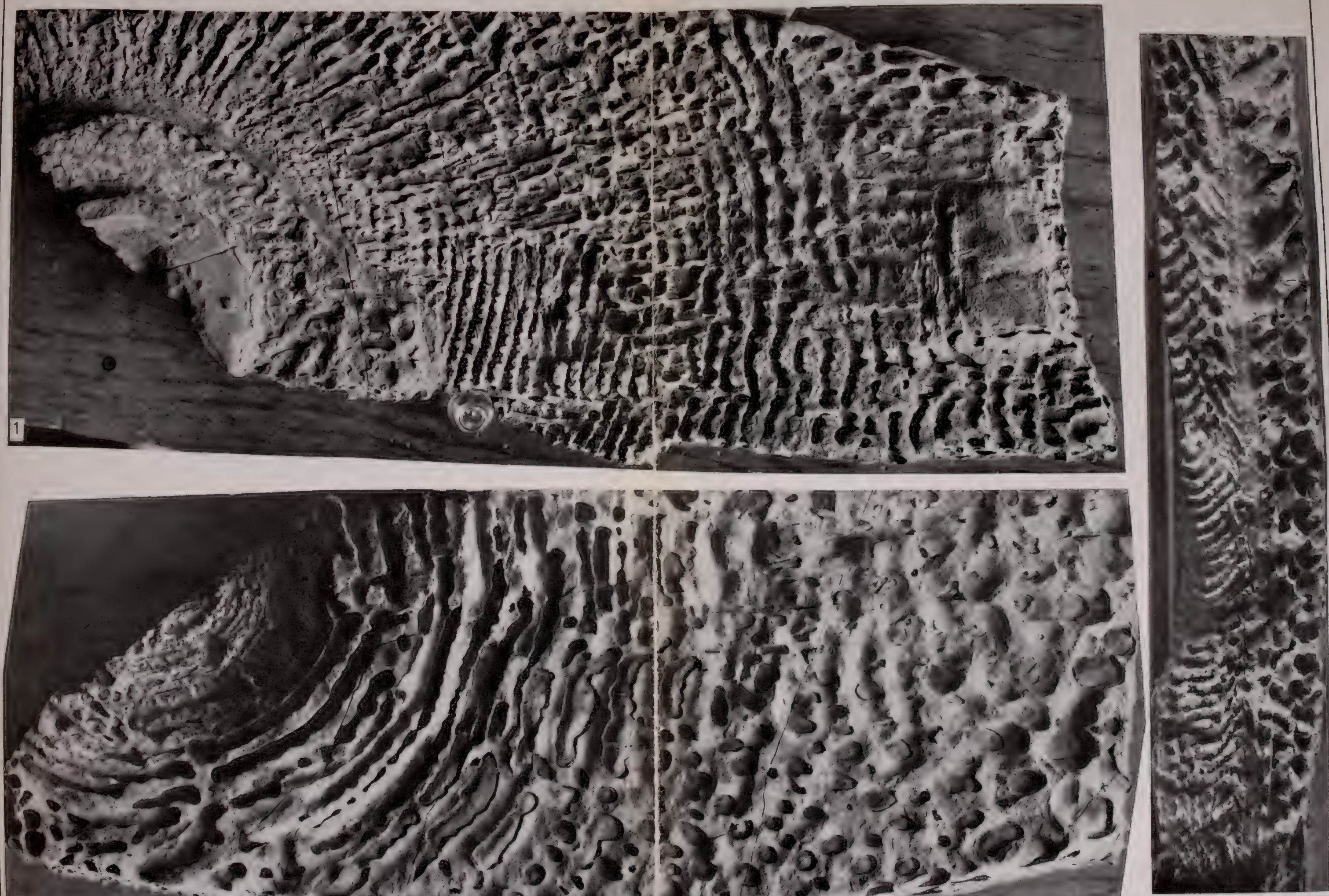
FIG. 1. (Natural size.) Portion of the upper surface of a large frond. 3 cm. in thickness, as shown by fig. 3. U. S. National Museum, Catalogue No. 60697.

2. (Natural size.) Lower surface of the specimen represented by fig. 1.

3. (Natural size.) Vertical section through the edge of the specimen represented by figs. 1 and 2. The laminated structure is toward the upper surface, the cellular structure forming the lower half.

The specimen represented by figs. 1-3 is a portion of a large frond that was 48 cm. or more in diameter, with an average thickness of 2.5 to 3 cm.

Locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



3

NEWLANDIA FRONDOSA Walcott

DESCRIPTION OF PLATE 7

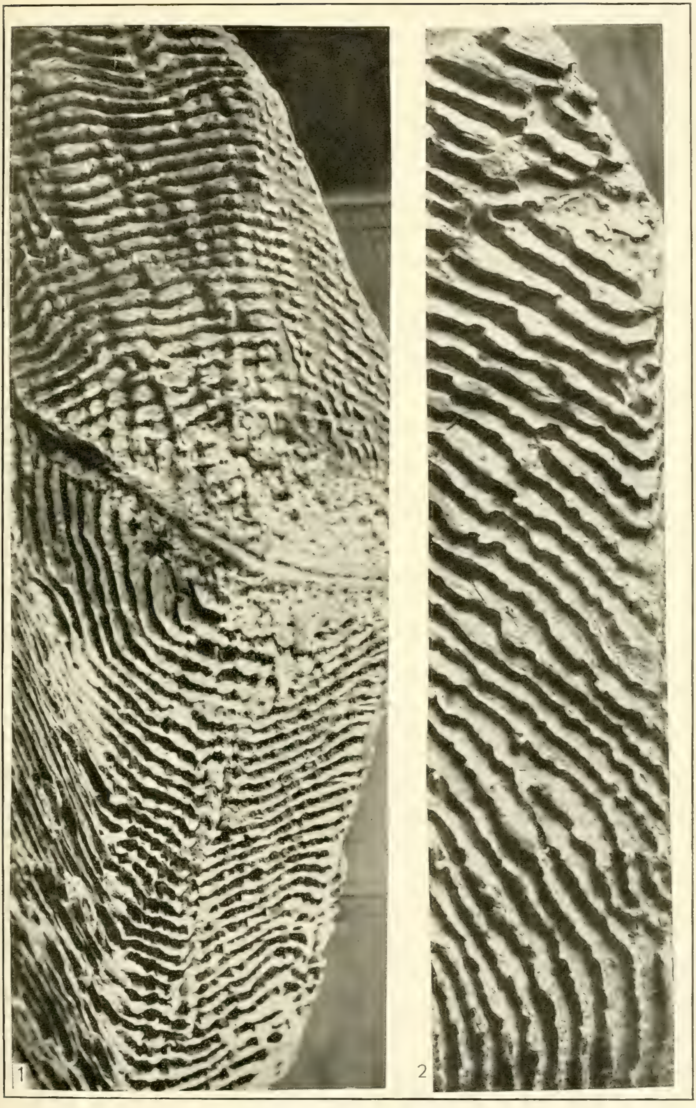
PAGE

Newlandia frondosa Walcott. (See pls. 5, 6, 8) 105

FIG. 1. (Natural size.) Oblique view of the vertical section of a large frond with a central concentric arrangement of the lamellæ in which there is almost no development of the coarse cellular structure shown by the illustrations on plate 6. U. S. National Museum, Catalogue No. 60698.

2. (Natural size.) View of a portion of the upper laminated surface of the specimen represented by fig. 1.

The specimen represented by figs. 1 and 2 is from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



NEWLANDIA FRONDOSA Walcott

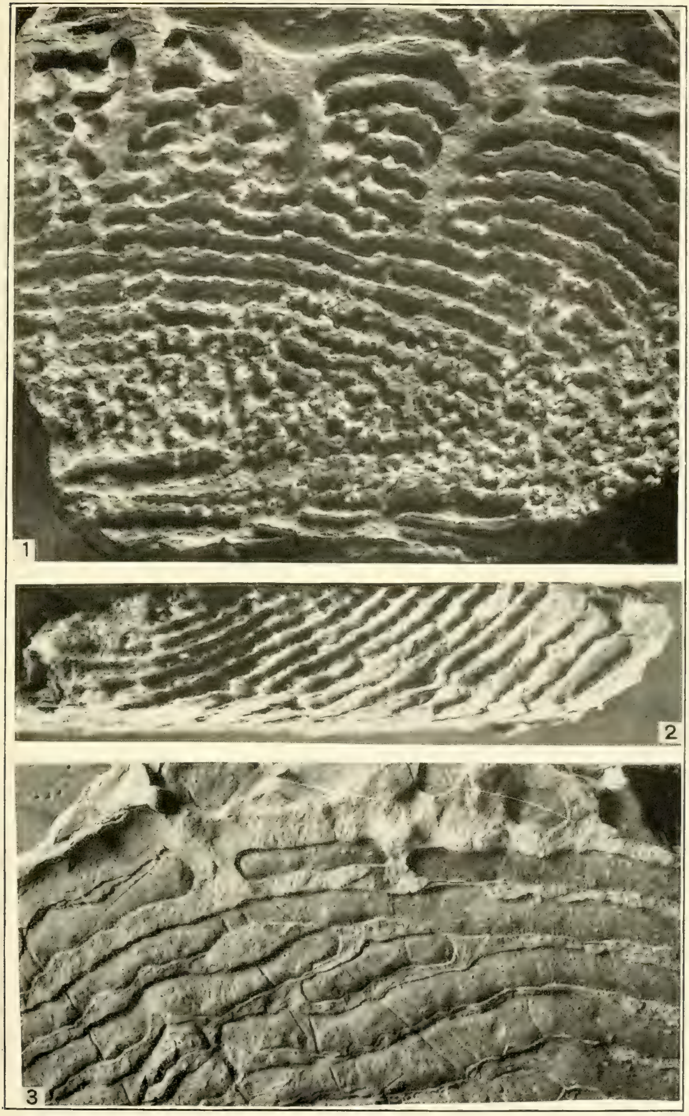
DESCRIPTION OF PLATE 8

PAGE

Newlandia frondosa Walcott. (See pls. 5-7) 105

FIGS. 1, 2, 3. (Natural size.) Views of the upper, vertical, and lower faces of a specimen showing somewhat different structure from that illustrated on plates 6 and 7. U. S. National Museum, Catalogue No. 60699.

The specimen represented by figs. 1-3 is from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



NEWLANDIA FRONDOSA Walcott

DESCRIPTION OF PLATE 9

PAGE

Camasia spongiosa Walcott. (See pl. 12) 115

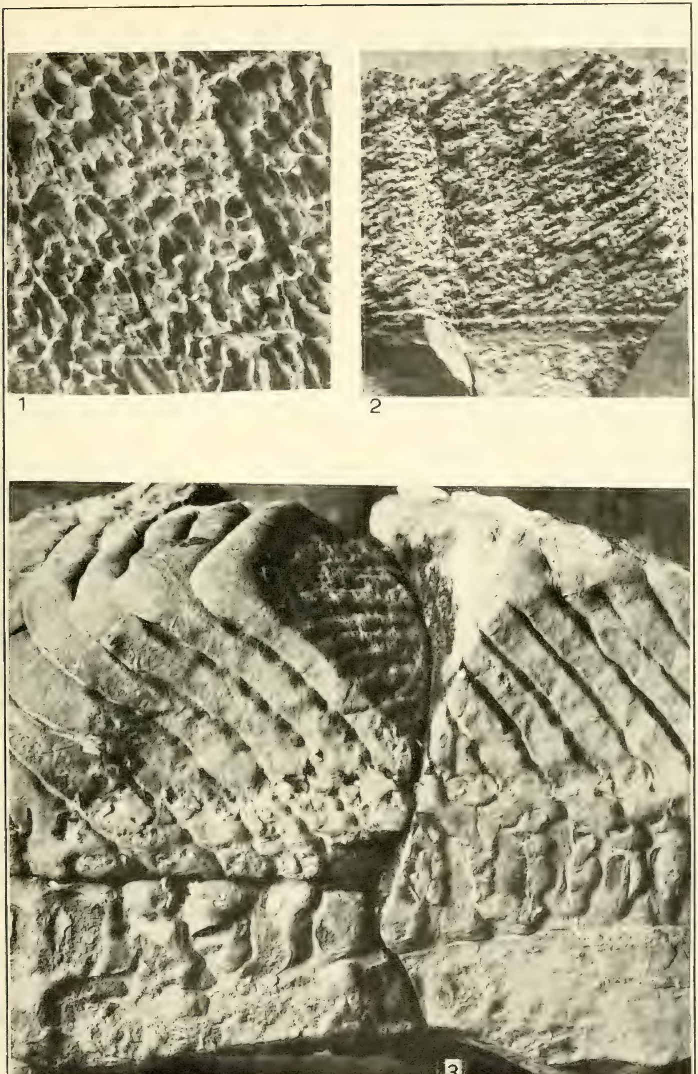
FIG. 1. (Natural size.) View of upper surface, showing the somewhat open cellular structure. U. S. National Museum, Catalogue No. 60700.

2. (Natural size.) Vertical view through the specimen represented by fig. 1, showing sponge-like growth and the thickness of the specimen, which has at its base a thin layer of limestone.

Newlandia major Walcott 105

FIG. 3. (Natural size.) Vertical section of a specimen in which the lamellæ are interrupted in their growth toward the bottom and then continue up through to the upper surface of the layer. U. S. National Museum, Catalogue No. 60701.

The specimens represented by figs. 1-3 are from locality 400c; Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



1, 2. CAMASIA SPONGIOSA Walcott

3. NEWLANDIA MAJOR Walcott

DESCRIPTION OF PLATE 10.

PAGE

Newlandia lamellosa Walcott.. 106

FIG. 1. (Natural size.) Vertical section of a specimen having very finely laminated structure. U. S. National Museum, Catalogue No. 60702.

2. (Natural size.) Upper surface of the specimen represented by fig. 1.

The specimen represented by figs. 1 and 2 is from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.

Collenia ? frequens (Walcott).. 113

FIG. 3. (About one-thirtieth of natural size.) Upper surface and section of a group of cylindrical forms. After photograph by Bailey Willis.

Locality: Algonkian: Siyeh limestone; Little Kootna Creek, Chief Mountain quadrangle, Montana.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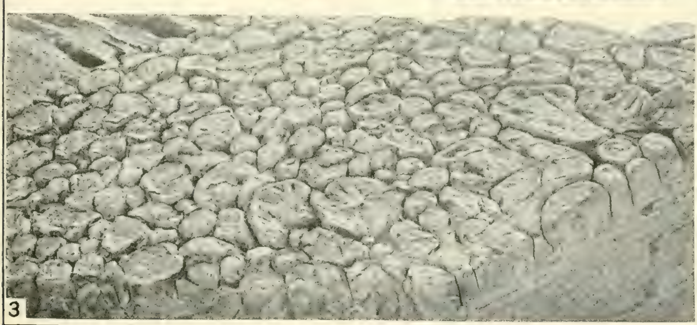
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1, 2. NEWLANDIA LAMELLOSA Walcott
3. COLLENIA ? FREQUENS (Walcott)

DESCRIPTION OF PLATE 11

PAGE

Weedia tuberosa Walcott 108

FIG. 1. (Natural size.) View of a weathered section of one of the large sphæroidal tubercles, showing something of the laminated structure. U. S. National Museum, Catalogue No. 60703.

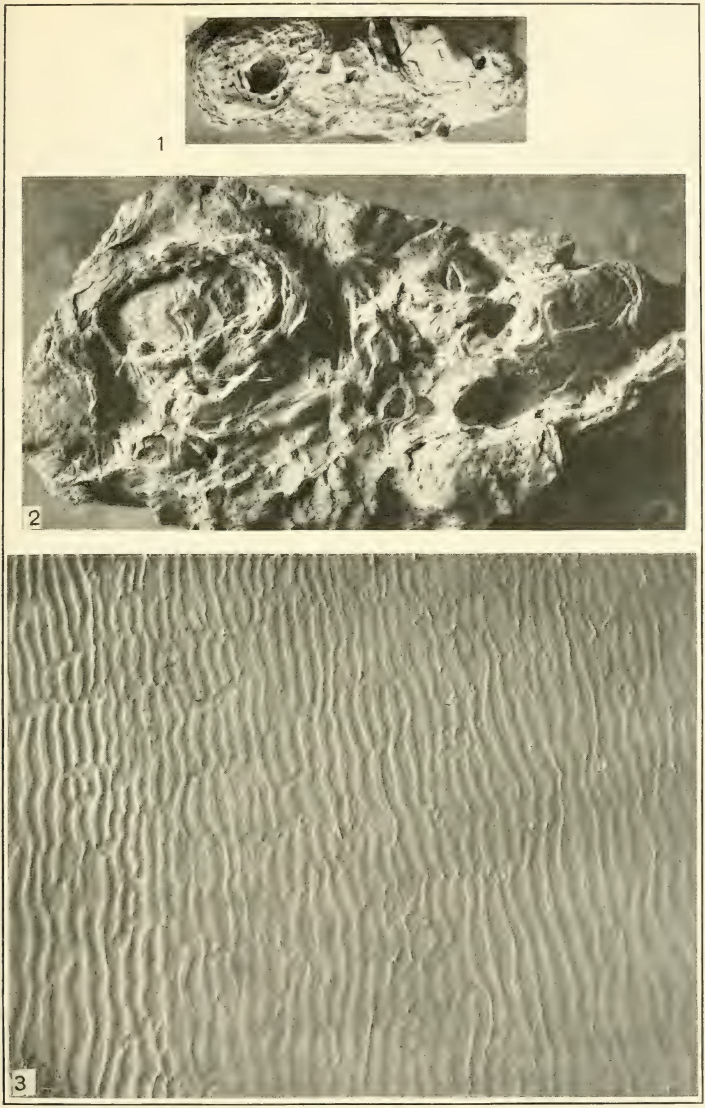
2. (Natural size.) View of the weathered surface of a group of large tubercles on the upper surface of a layer of limestone. U. S. National Museum, Catalogue No. 60704.

The specimens represented by figs. 1 and 2 are from locality **400**: Algonkian: Siyeh limestone; south side of Gunsight Pass, Glacial National Park, Montana.

Kinneyia simulans Walcott 107

FIG. 3. (Natural size.) View of upper surface of a specimen in which the irregular lamellæ extend almost vertically through the layer. U. S. National Museum, Catalogue No. 60705.

The specimen represented by fig. 3 is from locality **400c**: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



1, 2. WEEDIA TUBEROSA Walcott

3. KINNEYIA SIMULANS Walcott

DESCRIPTION OF PLATE 12

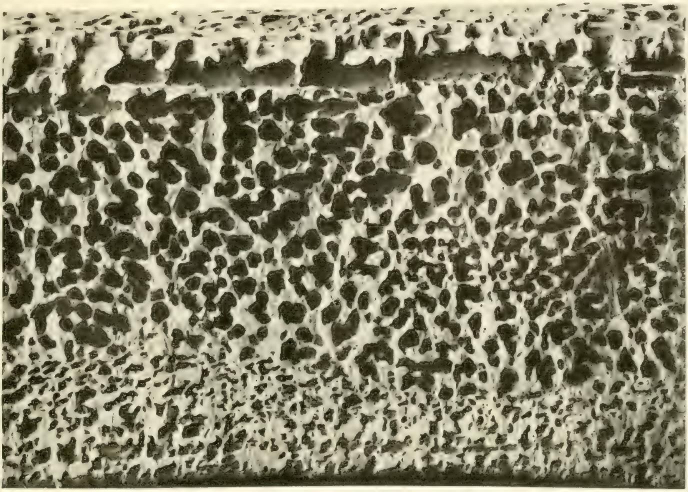
PAGE

Camasia spongiosa Walcott. (See pl. 9) 115

FIG. 1. (Natural size.) Vertical section through the side of a large block showing the vesicular character of the specimen. U. S. National Museum, Catalogue No. 60706.

2. (Natural size.) Vertical section of the same specimen as shown by fig. 1, at right angles to the section shown by fig. 1. The tubular openings are very irregular.

The specimen represented by figs. 1 and 2 is from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



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CAMASIA SPONGIOSA Walcott

DESCRIPTION OF PLATE 13

PAGE

Collenia undosa Walcott. (See pl. 14) 113

Fig. 1. (Natural size.) Vertical polished section through a layer in which numerous specimens are embedded. U. S. National Museum, Catalogue No. 60707.

Fig. 2. (Natural size.) Photograph of thin section of a subspherical specimen, showing the original growth as a dome and then a second growth that apparently occurred after the specimen had been rolled over. U. S. National Museum, Catalogue No. 60708.

The specimens represented by figs. 1 and 2 are from locality **400b**: Algonkian: Spokane shales; 8 miles (12.8 km.) west of White Sulphur Springs at forks of Birch Creek, Meagher County, Montana.

1

2

COLLENIA UNDOSA Walcott

DESCRIPTION OF PLATE 14

PAGE

Collenia undosa Walcott. (See pl. 13) 113

FIGS. 1 and 2. (0.5 natural size.) Side and top view of a group of specimens that have apparently grown together, forming a solid mass. They are embedded in the red Spokane shales. U. S. National Museum, Catalogue No. 60709.

Locality **400b**: Algonkian: Spokane shales; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.

1

2

COLLENIA UNDOSA Walcott

DESCRIPTION OF PLATE 15

PAGE

Collenia occidentale (Dawson) 111

FIG. 1. (Natural size.) Photograph of a thin-section showing portions of two fragments. U. S. National Museum, Catalogue No. 33799.

2. (× 8.) Enlargement of the lower, smaller fragment in fig. 1.

3, 4. (Natural size.) Photographs of two thin-sections occurring in the same stratum of rock as that represented by fig. 1. U. S. National Museum, Catalogue No. 33799.

5, 6. (Natural size.) Natural sections through two turbinate forms of growth. U. S. National Museum, Catalogue Nos. 60710, 60711.

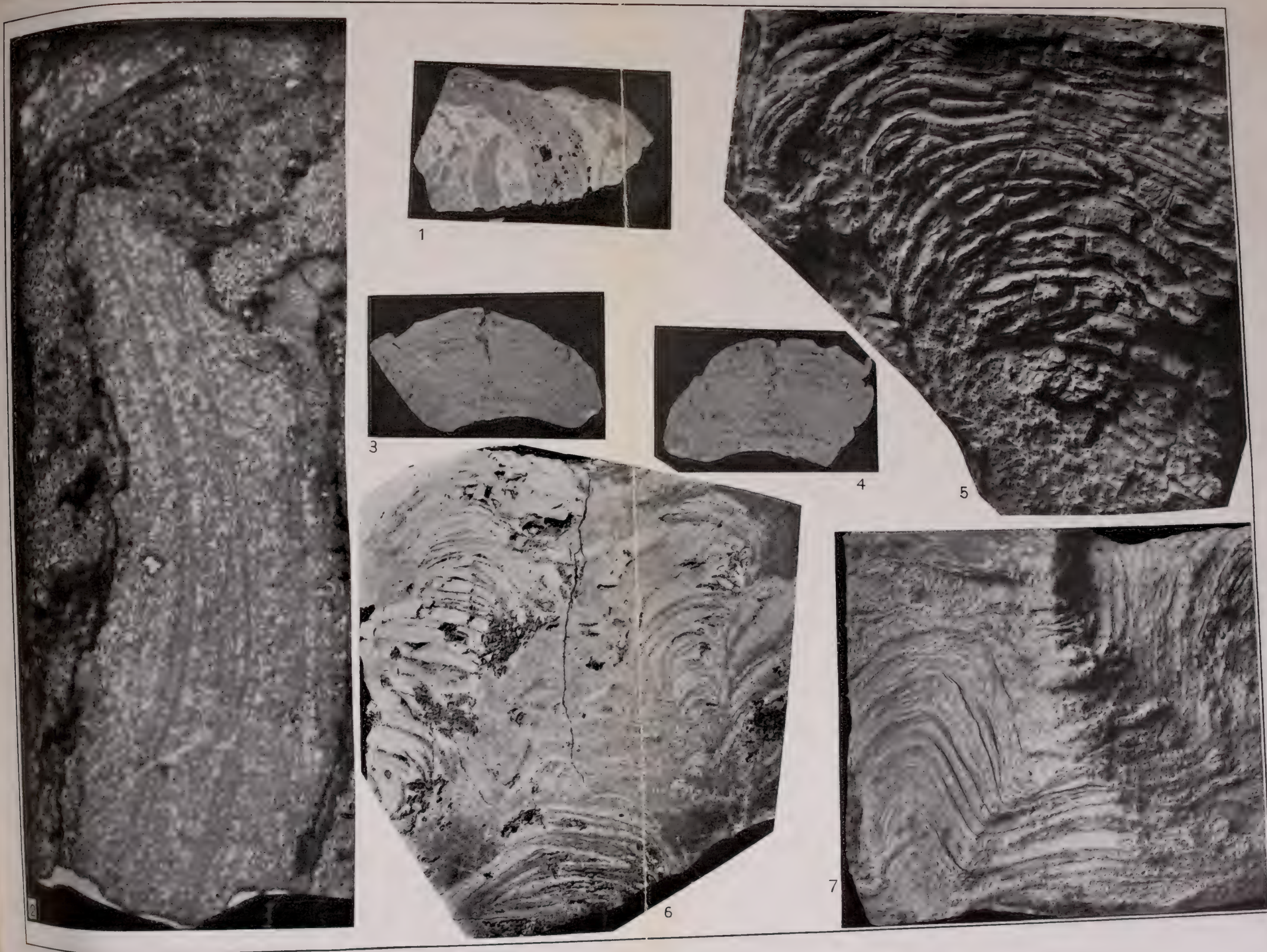
The specimens represented by figs. 1-6 are from the Algonkian: Chuar terrane; Grand Canyon, Arizona.

These figures (1-4) were published as figs. 1-4, plate 23, Bull. Geol. Soc. America, Vol. 10, 1898, Walcott: Pre-Cambrian fossiliferous formations.

Collenia compacta Walcott 112

FIG. 7. (Natural size.) Natural weathered vertical section showing the club-shaped growth on the left with the irregular lamellæ about it on the right. U. S. National Museum, Catalogue No. 60712.

From locality 400a: Algonkian: Siyeh limestone; Continental Divide at head of Kipps Creek, Glacial National Park, Montana.



COLLEN A

DESCRIPTION OF PLATE 16

PAGE

Cryptozoon proliferum Hall 111

FIG. 1. Glaciated exposure of one of the *Cryptozoan* reef beds of the Hoyt limestone, by the roadside near the Hoyt quarry, northwest of Saratoga, New York. Original locality of Hall's figure of the species.

This plate is published here through the courtesy of Dr. John M. Clarke, Director of the New York State Museum. It is plate 3 of Bulletin 169, 1914, of the Museum.

Cryptozoon proliferum is illustrated and referred to in my paper on the "New York Potsdam-Hoyt Fauna." Smithsonian Misc. Coll., Vol. 57, 1912, p. 258, pl. 37.

CRYPTOZOON PROLIFERUM Hall

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DESCRIPTION OF PLATE 17

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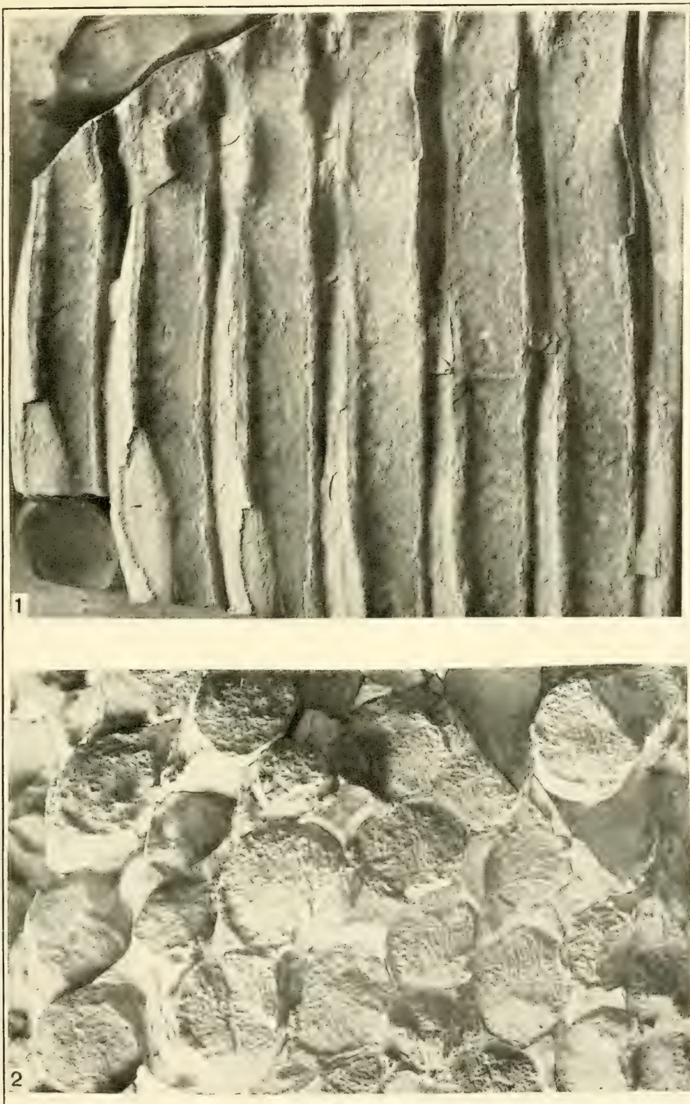
Greysonia basaltica Walcott. (See pl. 18)........................... 109

FIG. 1. (Natural size.) Section of a mass of the basaltic-like columns obtained by splitting off a group of the tubes. U. S. National Museum, Catalogue No. 60713.

2. (Natural size.) View of the end of the basaltic-like tubes. U. S. National Museum, Catalogue No. 60714.

The algæ form the interspaces between the tubes that are now filled with limestone.

The specimen represented by figs. 1 and 2 is from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



GREYSONIA BASALTICA Walcott

DESCRIPTION OF PLATE 18

PAGE

Greysonia basaltica Walcott. (See pl. 17) 109

Fig. 1. (Natural size.) Vertical section of a group of tubes forming a layer 5 cm. in thickness. U. S. National Museum, Catalogue No. 60715.

The tubes are filled with a bluish-black limestone and the algæ are represented by gray to grayish-yellow magnesian limestone.

The tubes were formed in a horizontal position, presumably as portions of a large frond.

2. (Natural size.) Lower surface of a specimen of which the upper surface is represented by fig. 2, pl. 17. U. S. National Museum, Catalogue No. 60714.

The tubes of this specimen appear to have grown in a vertical position, and have a length in the portions preserved of 18 cm.

The specimens represented by figs. 1 and 2 are from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.

GREYSONIA BASALTICA Walcott

DESCRIPTION OF PLATE 19

PAGE

Copperia tubiformis Walcott.. 110

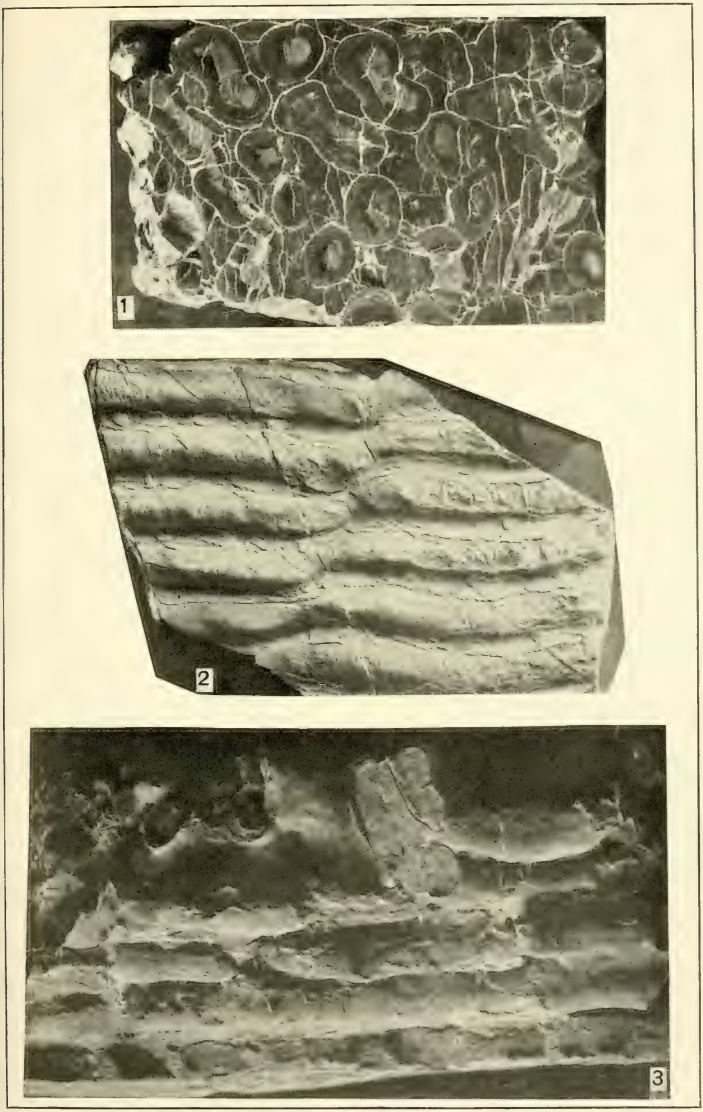
FIG. 1. (Natural size.) Polished vertical section of a group of more or less irregular tubes that form a layer 5.5 cm. thick. U. S. National Museum, Catalogue No. 60716.

2. (Natural size.) Surface of a group of tubes that were formed in a horizontal position. U. S. National Museum, Catalogue No. 60717.

3. (Natural size.) View of a natural section of a layer 5 cm. in thickness in which the three lower layers of tubes are fairly regular, while the upper layers show irregular growth. U. S. National Museum, Catalogue No. 60718.

This form occurs in layers or tubes that are more or less parallel to the bedding of the layer.

The specimens represented by figs. 1-3 are from locality 400c: Algonkian: Newland limestone; 8 miles (12.8 km.) west of White Sulphur Springs, Meagher County, Montana.



COPPERIA TUBIFORMIS Walcott

DESCRIPTION OF PLATE 20

PAGE

Newlandia frondosa Walcott. (See pls. 6, 7, 8) 105

FIG. 1. (× 500.) Drawing of a plate of opal-like silica containing numerous slender tubes, some of which have irregularly spaced partitions that have a distinct upper and lower surface that probably indicates organic origin. This type is not uncommon in material obtained by treating specimens of this species with hydrochloric acid. U. S. National Museum, Catalogue No. 60719.

Camasia spongiosa Walcott. (See pls. 9, 12) 101

FIG. 2. (× 350.) Chain of cells as photographed and partly outlined. The untouched micrograph is shown by fig. 4, where about half of the cells are in the focal plane. U. S. National Museum, Catalogue No. 60720.

3. (About × 1400.) Outline sketch of the chain shown by figs. 2 and 4.

4. (× 350.) Micrograph of a portion of the fragment of opal-like silica containing the chain of cells represented by figs. 2 and 3. There are also present numerous minute tubes similar to those illustrated by fig. 1.

5, 5*a*. (× 350.) A group of seven supposedly round cells as they occur free from the matrix. Similar bodies occur in the opal-like silica both singly and in groups. The untouched micrograph is shown by fig. 5*a*. U. S. National Museum, Catalogue No. 60722.

6, 6*a*. (× 350.) Untouched micrograph of an irregular chain-like group of round cells that are free from the matrix. The round cell-like bodies are outlined in fig. 6*a* as they appear when examined under the microscope. U. S. National Museum, Catalogue No. 60723.

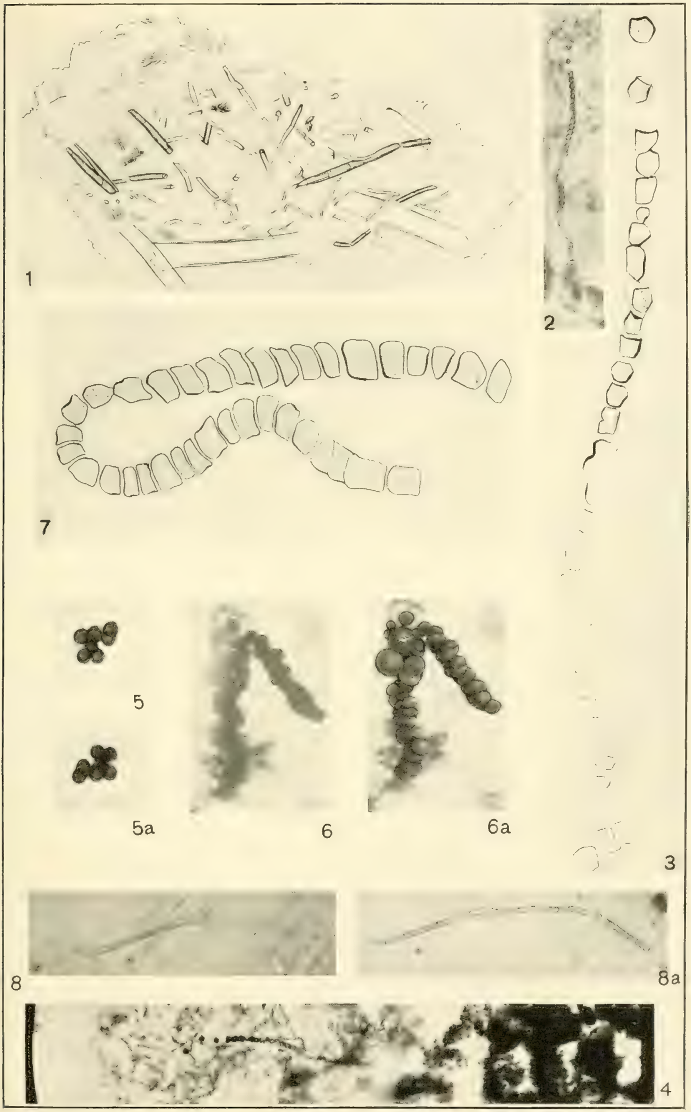
Blue-green algæ cells (*Schizothrix ?*) 100

FIG. 7. (About × 1200.) Outline drawing of a chain of cells obtained by treating a recent Blue-green algal calcareous deposit with hydrochloric acid. U. S. National Museum, Catalogue No. 60724.

8. (× 350.) Untouched photograph of a chain of cells obtained by treating a Blue-green calcareous deposit from Green Lake, Onondaga County, New York, with dilute hydrochloric acid.

8*a*. The same as fig. 8, with all the cells of the chain outlined. The chain is free except where entangled with diatoms and bits of opal-like silica. U. S. National Museum, Catalogue No. 60725.

The slides represented by figs. 7 and 8 were sent to me by Dr. Charles A. Davis. The material containing the cells represented by fig. 7 is from North Lake, Waukesha County, Wisconsin, 27 miles (43 km.) west-northwest of St. Paul, and that by fig. 8 from Green Lake, Onondaga County, New York.



MICROSCOPIC CELLS FROM RECENT BLUE-GREEN ALGÆ AND THEIR ALGONKIAN REPRESENTATIVES

DESCRIPTION OF PLATE 21

Annelid Trails on Greyson Shales

PAGE

Helminthoidichnites ? neihartensis Walcott.......................... 98

FIG. 1. (Natural size.) Two nearly parallel trails, with many small, dark, thin, flattened, usually circular concretions attached to them. U. S. National Museum, Catalogue No. 33795.

2. (Natural size.) Apparently a single trail made by the animal turning about and finally returning nearly on the line of the first trail. There are not as many concretions as in fig. 1. U. S. National Museum, Catalogue No. 33795.

3. (About × 10.) Enlargements of one of the small disc-like concretions associated with figs. 1 and 2. U. S. National Museum, Catalogue No. 33795.

4. (Natural size.) Same as figs. 1 and 2, but with many convolutions. This form is less common than the straight and partly curved trails shown by figs. 1 and 2. U. S. National Museum, Catalogue No. 33795.

Helminthoidichnites ? spiralis Walcott.............................. 98

FIGS. 5. 6. (Natural size.) Two figures illustrating the typical form of trail made by this curious species. U. S. National Museum, Catalogue No. 33794.

Helminthoidichnites meeki Walcott................................ 98

FIG. 7. (Natural size.) Illustration of the type specimen of the species. U. S. National Museum, Catalogue No. 33793.

The specimens represented by figs. 1-7 are from the Algonkian: Belt (Greyson shales) terrane; Deep Creek Canyon and Sawmill Canyon, Belt Mountains, Montana.

Planolites corrugatus Walcott...................................... 98

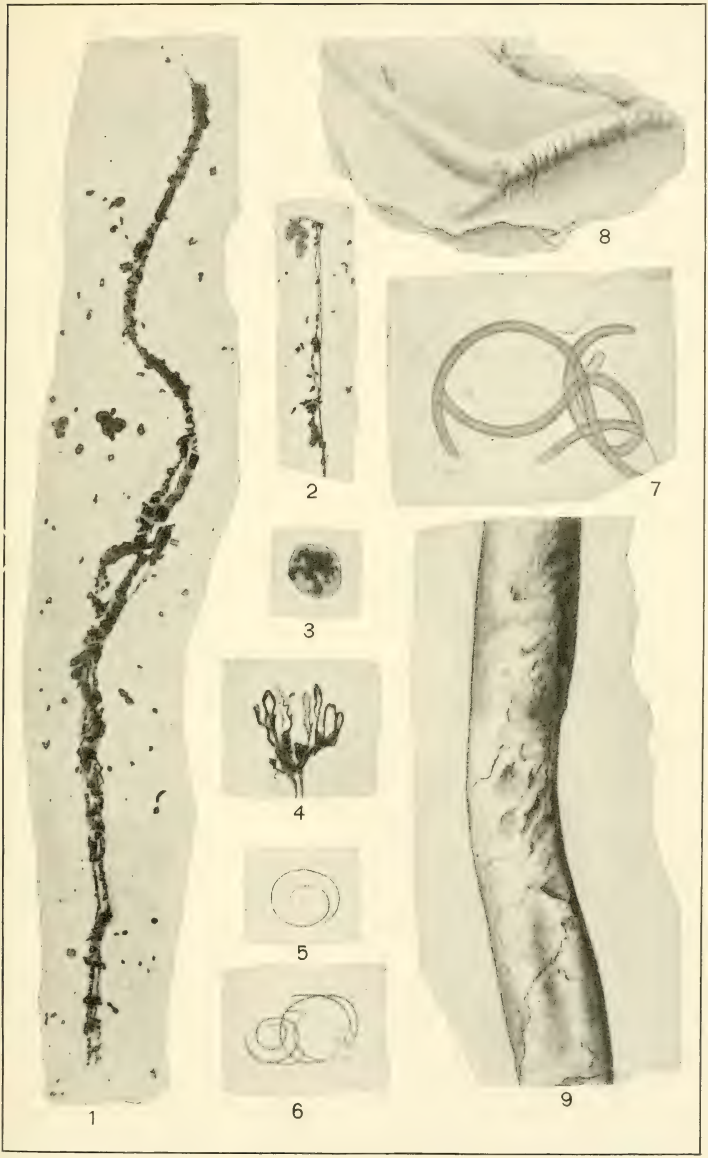
FIG. 8. (Natural size.) Exterior cast of the burrow made by medium-sized annelid in siliceous mud now forming the shales carrying *Beltina danai* Walcott. U. S. National Museum, Catlogue No. 33796.

Planolites superbus Walcott.. 98

FIG. 9. (Natural size.) A portion of the cast of a long burrow occurring in a sandy shale interbedded in the *Beltina danai* shales. U. S. National Museum, Catalogue No. 33797.

The specimens represented by figs. 8 and 9 are from the Algonkian: Greyson shales; Sawmill Canyon, 4 miles (6.4 km.) above Neihart, Cascade County, Montana.

This plate was published as plate 24, Bull. Geol. Soc. America, Vol. 10, 1898, Walcott: Pre-Cambrian Fossiliferous Formations.



ANNELID TRAILS

DESCRIPTION OF PLATE 22

Crustacean Remains from Greyson shales

PAGE

Beltina danai Walcott.. 98

FIGS. 1, 2. (Natural size.) Specimen which appears to represent the head. Fig. 2 is greatly compressed and distorted in front and probably belongs to another species. U. S. National Museum, Catalogue No. 33790.

3. (Natural size.) A segment of the body. U. S. National Museum, Catalogue No. 33790.

4. (× 3.) Portion of an appendage with four joints indicated. U. S. National Museum, Catalogue No. 33790.

5. (× 4.) An unidentified fragment with a small terminal curved spine. U. S. National Museum, Catalogue No. 33790.

6. (× 2.) An appendage with two large basal ? joints and two smaller terminal joints. U. S. National Museum, Catalogue No. 33790.

7. (Natural size.) Appendage with a large basal ? joint and four smaller joints indicated. U. S. National Museum, Catalogue No. 33790.

8. (Natural size.) Appendage with very large basal ? joint and several small joints. U. S. National Museum, Catalogue No. 33790.

9. (× 2.) Appendage with fragment of large basal ? joint and several small joints. U. S. National Museum, Catalogue No. 33790.

10. (Natural size.) Two appendages that are apparently attached to a single basal ? joint. U. S. National Museum, Catalogue No. 33790.

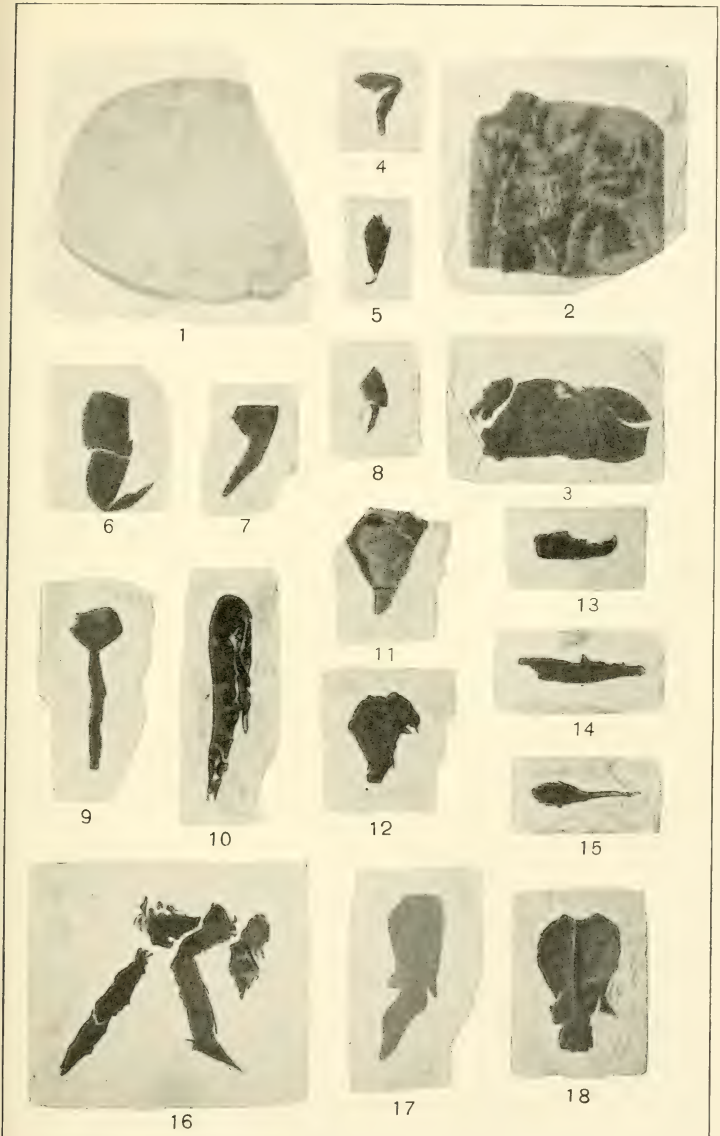
11. (Natural size.) Appendage with a broad basal ? joint. U. S. National Museum, Catalogue No. 33790.

12. (× 3.) Appendage with a broad basal ? joint. Several fine setæ or spines are attached to it. U. S. National Museum, Catalogue No. 33790.

13. (Natural size.) Movable ramus of a chelate appendage, with traces of teeth. U. S. National Museum, Catalogue No. 33790.

14. (Natural size.) Broken fixed portion of a chelate appendage, with traces of teeth. U. S. National Museum, Catalogue No. 33790.

15. (Natural size.) Several specimens of this character occur in the collection. U. S. National Museum, Catalogue No. 33790.



BELT TERRANE FOSSILS

Beltina danai Walcott—Continued.

Fig. 16. (Natural size.) Jointed appendages very much compressed and distorted. U. S. National Museum, Catalogue No. 33790.

17. (Natural size.) Jointed appendage. U. S. National Museum, Catalogue No. 33790.

18. (Natural size.) Telson preserving a central ridge. U. S. National Museum, Catalogue No. 33790.

The specimens represented on this plate are from the Algonkian: Greyson shales; Deep Creek Canyon, near Glenwood, and Sawmill Canyon, 4 miles (6.4 km.) above Neihart, Cascade County, Montana.

This plate was published as plate 25, Bull. Geol. Soc. America, Vol. 10, 1898, Walcott: Pre-Cambrian Fossiliferous Formations.

DESCRIPTION OF PLATE 23

PAGE

Gallatinia pertexa Walcott.................................... 116

Fig. 1. (Natural size.) View of upper surface of type specimen. U. S. National Museum, Catalogue No. 60730.

2. (Natural size.) Vertical section through specimen represented by fig. 1.

The specimen illustrated is from locality 400j: Algonkian: Belt terrane; north of Bartons Bridge on the Gallatin River, Montana.

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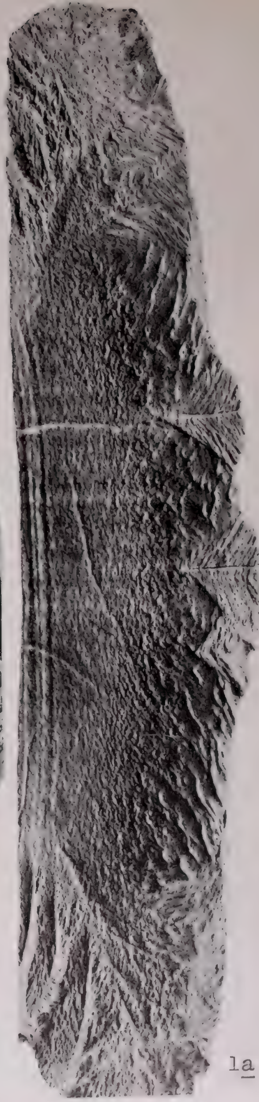

1a

GALLATINIA PERTEXA, Walcott

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 64, NUMBER 3

CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 3.—CAMBRIAN TRILOBITES

(With Plates 24 to 38)

BY
CHARLES D. WALCOTT

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 3.—CAMBRIAN TRILOBITES

By CHARLES D. WALCOTT

(With Plates 24 to 38)

CONTENTS

PLATES

INTRODUCTION

The present paper is the second of this series on Cambrian Geology and Paleontology that bears the title "Cambrian Trilobites." The first, published in 1908,[1] includes descriptions and illustrations of a number of unusual Middle Cambrian genera and species. Several subsequent papers have dealt with trilobites of a particular family or genus or from a stratigraphic view.

These include:

"*Olenellus* and other Genera of the Mesonacidæ." [Smithsonian Misc. Coll., Vol. 53, No. 6, 1910.]

"Cambrian Faunas of China." [*Idem*, Vol. 57, No. 4, 1911.]

"Middle Cambrian Branchiopoda, Malacostraca, Trilobita, and Merostomata." [*Idem*, Vol. 57, No. 6, 1912.]

"Cambro-Ordovician Boundary in British Columbia with Description of Fossils." [*Idem*, Vol. 57, No. 7, 1912.]

"The Sardinian Cambrian Genus *Olenopsis* in America." [*Idem*, Vol. 57, No. 8, 1912.]

"New York Potsdam-Hoyt Fauna." [*Idem*, Vol. 57, No. 9, 1912.]

"New Lower Cambrian Subfauna." [*Idem*, Vol. 57, No. 11, 1913.]

"*Dikelocephalus* and other Genera of the Dikelocephalinæ." [*Idem*, Vol. 57, No. 13, 1914.]

"Cambrian Faunas of Eastern Asia." [*Idem*, Vol. 64, No. 1, 1914.]

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[1] "Cambrian Trilobites," Smithsonian Misc. Coll., Vol. 53, No. 2, pp. 13-52, pls. 1-6.

The memoir on the Cambrian Faunas of China[1] also contains many descriptions and illustrations of trilobites.

One of the marked features of the present paper is the description of several genera of the order Proparia: *Menomonia, Millardia, Dresbachia,* and *Norwoodia.* These taken in connection with the genus *Burlingia,*[2] of the Middle Cambrian, establish the existence of a strong group of the order in Cambrian time.

CHANGE IN STRATIGRAPHIC POSITION OF THE WEEKS FORMATION[3]

On account of the presence of *Crepicephalus texanus* Shumard in the Weeks formation, the strata forming it were referred to the Middle Cambrian. My recent studies of *C. texanus* and its stratigraphic and geographic range have led me to the conclusion that it is an Upper Cambrian species and that the formations containing it should be referred to the Upper Cambrian. This question will be considered in detail in a subsequent paper on the Upper Cambrian formations.

DESCRIPTIONS OF GENERA AND SPECIES

Order PROPARIA Beecher

Family MENOMONIDÆ, new family

Proparia of primitive aspect, with large free cheeks; eyes small. Thorax with 23 to 42 segments; pygidium small.

The genera referred to this family are *Menomonia, Millardia,* and *Dresbachia.*

MENOMONIA, new genus

General form elongate, lance-shaped, with cephalon at the broad end; strongly convex; axial and pleural lobes strongly outlined.

Cephalon transversely semicircular with rounded genal angles on the postero-lateral limbs; marginal border broad and convex on the cranidium, flattening out on the free cheeks; posterior margin strongly defined by a deep furrow that merges into the intramarginal furrow of the free cheek. Glabella truncato-conical, about one-half the length of the cranidium, and marked by three pairs of short lateral furrows; occipital ring of medium width and well defined by

[1] Research in China, Carnegie Inst. of Washington, 1913, Vol. 3, Pub. No. 54, pp. 1-276, pls. 1-24.

[2] Cambrian Trilobites, Smithsonian Misc. Coll., Vol. 53, No. 2, 1908, p. 14.

[3] Nomenclature of some Cambrian Cordilleran Formations, Smithsonian Misc. Coll., Vol. 53, No. 1, 1908, p. 10.

a strong occipital furrow; frontal limb of medium width, and arching up into a broad convex frontal border. Fixed cheeks narrow and separated from the glabella by a strong, narrow furrow from which they slope upward to the small palpebral lobes, which are situated opposite the anterior end of the glabella; postero-lateral limbs large, rounded at the genal angles. Free cheek elongate, broad at anterior end, where it joins the frontal limb and border. Eye lobe small and prominent at the inner anterior angle of the cheek.

The facial suture cuts the outer postero-lateral side of the cephalon in advance of the genal angle, and passes almost directly inward to the base of the eye; arching over the eye, it passes with a slight outward curve forward to the front margin.

Thorax with 42 segments; axial lobe convex with each segment strongly rounded; pleural lobes convex with each segment carrying a strong flat furrow from the inner end nearly to the outer termination of the segment.

Pygidium very small; axial lobe well defined and broken into two or three rings and a terminal section by transverse furrows; pleural lobes smooth in cast of test, but probably marked by faint, short, backward-curving furrows.

Surface unknown except that the casts in a fine sandstone are smooth.

Dimensions.—The largest cranidium indicates that some dorsal shields had a length of at least 45 mm.

Genotype.—*Conocephalites calymenoides* Whitfield.

Stratigraphic range.—Upper Cambrian: Eau Claire formation.

Geographic distribution.—Upper Mississippi Valley in central western Wisconsin and eastern Minnesota.

Observations.—This very remarkable trilobite resembles the genus *Calymene* in the form of the cranidium and free cheeks, while the thoracic segments have the straight, strong pleural furrow of *Ptychoparia.* The great number (42) of segments is a very primitive character and gives the thorax an annelidian aspect.

MENOMONIA CALYMENOIDES (Whitfield)

Plate 26, figs. 4, 4*a-d*

Conocephalites calymenoides WHITFIELD, 1878, Ann. Rept. Geol. Survey Wisconsin for 1877, p. 52. (Original description.)

Conocephalites calymenoides WHITFIELD, 1882, Geol. Wisconsin, Vol. 4, p. 179, pl. 3, figs. 2-5. (Describes and illustrates species.)

Conocephalites calymenoides Whitfield, CHAMBERLIN, 1883, Geol. Wisconsin, Vol. 1, p. 131, fig. 17*d*. (Reproduces fig. 2 of Whitfield in Vol. 4.)

Whitfield's description of the cranidium and thorax as far as he knew it is very full and does not need to be repeated in detail. The cranidia are abundant in the Eau Claire sandstone at Rock Falls, Wisconsin, and the associated free cheeks which appear to belong to them. One of these, illustrated by figure 4*d*, plate 26, has a small eye, and a strong marginal rim that curves backward to join the border of the postero-lateral limb in advance of the genal angle; this is rounded as seen on the right side of figure 4, plate 26.

Whitfield described an incomplete thorax having 22 segments. The specimen illustrated by figures 4*b* and 4*c* has 42 thoracic segments, the dorsal shield narrowing very gradually from the cephalon to the pygidium.

Pygidium minute; axial lobes short and divided into two or three rings and a terminal section by shallow transverse furrows; pleural lobes smooth as far as may be determined from the cast in a fine sandstone matrix.

Exterior surface unknown except that the casts in fine sandstone are nearly smooth.

A specimen of the thorax and pygidium is 25 mm. in length. A cephalon of the width to correspond to the anterior segments of the thorax has a length of 7 mm. The largest cranidium in the collection has a length of 10 mm.

Observations.—The general characters of the species are included in the description of the genus.

Formation and locality.—Upper Cambrian: (78a and 98) Eau Claire formation; near Eau Claire, Eau Claire County: (83a) Rock Falls, and (100) Menomonie, Dunn County; also from (83^4) Dresbach formation; lower beds just above the river, Trempealeau, Trempealeau County, both in Wisconsin. Also from (84) Eau Claire formation; Dresbach, Winona County, Minnesota.

MILLARDIA, new genus

General form elongate elliptical; convex; axial and pleural lobes strongly defined.

Cephalon transversely broadly elliptical with genal angles rounded; margined with a rounded distinct border and intramarginal furrow; glabella subtriangular in outline, convex, and marked by three pairs of short lateral furrows; occipital ring and furrow strongly defined; frontal limb short, slightly convex, and depressed between the glabella and the strong rounded frontal border; frontal border arched upward between the points cut by the facial sutures; fixed cheeks

narrow and elevated at the palpebral lobe; postero-lateral limbs long and retaining nearly the same width from the glabella to their outer side, which is rounded at the genal angle; palpebral lobes small, elevated, and situated opposite the anterior end of the glabella.

Free cheeks large, elongate, convex, with the eye lobe at the inner anterior angle.

The facial sutures cut the postero-lateral margin in advance of the genal angle and pass obliquely inward to the base of the small eye lobes, over which they curve before passing forward to the anterior margin.

Thorax with 23 segments; axial lobe convex, with each segment rounded and prominent; pleural lobes flat for a short distance from the dorsal furrow, and then arched downward; pleural furrows short and narrow; segments rounded at the end of their broad faceted surface.

Pygidium small, transverse; axial lobe short and divided into two or three rings by transverse furrows that are continued across the pleural lobes to their outer margin.

Surface marked with very fine granulations and a few large granules that are prominent on the glabella, frontal border, and segments of the thorax.

Dimensions.—The largest dorsal shield has a length of 9 mm. and a width of 6 mm. at the base of the cephalon.

Genotype.—*Millardia semele* Walcott.

The generic name is from Millard County, Utah.

Stratigraphic range.—*Millardia semele* occurs in the Weeks formation of the Upper Cambrian of Utah, *M. optata* in the lower part of the Upper Cambrian in the Eau Claire formation of Wisconsin, and *M. avitas* in the Upper Cambrian of Pennsylvania.

Geographic distribution.—*Millardia semele* is from Millard County, western Utah; *M. optata* is found in western Wisconsin, near Hudson, St. Croix County, and *M. avitas* is from Pennsylvania.

Observations.—The cranidium of *Millardia* is much like that of *Dresbachia* and *Menomonia* (pl. 26). It differs from both mainly in the character of the frontal limb and border, and also from *Menomonia* in having about one-half as many thoracic segments. All three genera have the facial sutures cutting the border of the cephalon in advance of the genal angle, and all agree in the eyes being situated opposite the anterior end of the glabella.

MILLARDIA AVITAS, new species

Plate 28, figs. 5, 5*a-c*

This species is represented by two very distinct cranidia. These differ in so many respects from the other species of the genus that detailed description and comparisons do not appear to be necessary. The most nearly related form is *M. optata* (see pl. 28, figs. 4, 4*a-b*) from the Upper Cambrian of Wisconsin. With a strong lens the surface is seen to be roughened by minute granules of varying size.

This species is of special interest, as it serves as a link between the Upper Cambrian fauna of the Appalachian trough in Pennsylvania and that of the Eau Claire subfauna of the Upper Cambrian of the upper Mississippian province.

Formation and locality.—Upper Cambrian: (107k) Buffalo Run[1] limestone, 2 miles (3.2 km.) north of Benore Post Office, Center County, Pennsylvania.

MILLARDIA OPTATA (Hall)

Plate 28, figs. 4, 4*a-f*

Conocephalites optatus HALL, 1863, Sixteenth Ann. Rept., New York State Cab. Nat. Hist., p. 222, pl. 5A, fig. 7. (Describes and illustrates species.)

The type specimen of this species consists of the central portion of a cranidium showing the glabella, occipital ring, frontal limb and margin, and a narrow fragment of the fixed cheeks.

Entire specimens of the cephalon show it to have been semicircular in outline, strongly convex, and with rounded genal angles. The glabella and other parts are essentially similar to those of the cranidium of *M. semele*. The differences between the two species are: the more transversely elongate outline of the cranidium of *M. semele;* the nearer approach of the posterior end of the facial suture to the genal angle in *M. optata*.

Casts of the outer surface of the test of *M. optata* indicate that it had a granular surface.

Formation and locality.—Upper Cambrian: (79c) Eau Claire formation; sandstones at Willow River Falls, a few miles from Hudson, St. Croix County; and (100a) Ettrick, Trempealeau County, both in Wisconsin. Also from (84) Eau Claire formation; Dresbach, opposite the mouth of Black River, Winona County, Minnesota.

The specimen described by James Hall is stated to have come from the "lower beds near Trempealeau," Wisconsin.

---

[1] A provisional name suggested by Mr. E. F. Moore.

The specimens illustrating this species were collected by Mr. W. A. Finkelnburg, of Winona, Minnesota, who presented them to the United States National Museum.

MILLARDIA SEMELE, new species

Plate 28, figs. 3, *3a-c*

The generic description is based on this species as the type. It is represented in the collections by two nearly entire specimens of the dorsal shield and a number of cranidia, which are closely related in form to those of *M. optata*.

Formation and locality.—Upper Cambrian: (30n) Weeks formation (1*c* of section);[1] also (30 o) (1*b* of section) north side of Weeks Canyon, 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

DRESBACHIA, new genus

General form of cephalon transversely crescentric; the posterior margin arching forward from the lateral margins, strongly convex. Glabella subtriangular in outline and marked by three pairs of oblique, short, deep lateral furrows; occipital ring strong and sharply defined by a narrow, deep occipital furrow. The frontal limb and border appear to be represented by a narrow projection in front of the glabella that has a deep longitudinal furrow which terminates at a narrow frontal rim. The sides of the furrow appear as though the test had been folded downward, leaving only a narrow strip at the top next to the facial suture.

On a small cranidium 1 mm. in length the frontal border projects very much as in *Proampyx acuminatum* (Angelin), but, unlike the nasute projection of the latter species, it has a longitudinal furrow that extends forward from in front of the glabella, which is the beginning of the deep furrow present on cranidia 3 to 5 mm. in length.

Fixed cheeks large, elongate, and arched backward; a strong intramarginal furrow extends from the dorsal furrow beside the glabella out on the cheek, where it fades away before reaching the outer margin. The palpebral lobe has not been seen; it is probably situated by the side of the narrow projection in front of the glabella or else is very small and located toward the anterior end of the fixed cheek. As the test is not preserved, there is only the cast in fine sandstone to show details of structure.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 178.

Free cheeks large and shaped much like those of *Menomonia* (pl. 26, fig. 4*d*), except that they curve inward anteriorly so as to form a narrow, slightly elevated portion that fitted against the side of the projection in front of the glabella; as far as can be determined, the eye was at the interior anterior end of the free cheek; posteriorly the free cheek curves in against the fixed cheek in advance of the genal angle.

Dimensions.—A cranidium 7 mm. in length, including the narrow frontal limb, has a width of about 16 mm.

Genotype.—*Dresbachia amata* Walcott.

Stratigraphic range.—As far as known, the genus is found only in the sandstones of the Eau Claire and Franconia formations.

Geographic distribution.—Upper Mississippi Valley; central and western Wisconsin, and eastern Minnesota.

Observations.—Of this genus we have only the cranidium and free cheeks of one species. These indicate a type allied to *Menomonia calymenoides*, although the cranidia differ greatly in the form of the frontal limb and border and the free cheeks. The same is true of *Millardia* (pl. 28, figs. 3, 3*a*, 4, 4*a-b*) in respect to the frontal limb and border. The distinction between *Dresbachia* and *Millardia* is in the character of the frontal limb and border. *Dresbachia* is unique in the conformation of the narrow, deeply furrowed frontal limb.

DRESBACHIA AMATA, new species

Plate 26, figs. 5, 5*a-c*

The description given of the genus *Dresbachia* includes what is known of the species. It has hitherto been confused with *Millardia optata* (Hall) (pl. 28, figs. 4, 4*a-f*), as the cranidia have similar fixed cheeks and glabella, but differ very much in the form of the frontal limb and border.

The fragmentary remains of the cephalon are quite abundant at a number of localities, but thus far I have not learned of an entire dorsal shield having been found.

Formation and locality.—Upper Cambrian: (78a and 98x) Eau Claire formation; Eau Claire, Eau Claire County; (79) near Hudson, St. Croix County; (79x) Beaver Creek, north of Galesville, Trempealeau County; (100) near Menomonie, Dunn County; and (100a) at Ettrick, Trempealeau County; all in Wisconsin.

Also from (84) Eau Claire formation; Dresbach, Winona County; (84a) Franconia formation; River Junction, Houston County, Minnesota.

NORWOODIDÆ, new family

Proparia with 8 or 9 segments; strongly developed spines at genal angles; eyes small, but well developed.

This family combines primitive characters with those of a more highly developed type. The cranidium with its *Ptychoparia*-like glabella and small eyes, and the broad pleural furrows, are primitive (Calymenidæ-like), while the few segments of the thorax (9) and the relatively large pygidium suggest the subfamily Phacopinæ.

NORWOODIA, new genus

General form a broad ellipse, moderately convex, with pleural lobes more or less flattened. Cephalon semicircular with the genal angles prolonged as strong spines; cranidium elongate with narrow fixed cheeks and medium-sized palpebral lobes; glabella conical and marked with three pairs of short lateral furrows; frontal limb distinct or merging into the frontal border; postero-lateral limbs large, transverse, and carrying a strong spine at the genal angle; free cheeks large, roughly subtriangular, and with the eye lobe at the inner posterior angle.

Thorax with eight or nine transverse segments; axial lobe strong, convex; pleural lobes with each segment having a broad, strong median furrow that terminates just within the more or less bluntly falcate pointed extremity. A sharp, slender median spine similar to the occipital spine of the cephalon occurs on the third, fifth, and seventh segments of the thorax of *N. tenera,* as shown by figure *2d,* plate 28, which has the spine of the seventh segment attached to the axial lobe; the point of attachment is also shown on the axial lobe of figure *2b;* similar thoracic spines occur on *N. gracilis* (fig. *2f,* pl. 27) and *N. simplex* (fig. 3*b*).

Pygidium transverse; axial lobe strong and divided by narrow transverse furrows into two or three rings and a terminal section; pleural lobes broad and marked by backward-curving narrow furrows.

Surface minutely granular with larger scattered granules on *Norwoodia tenera,* which is the only species preserving the test in good condition.

Dimensions.—All the species of the genus are small. A dorsal shield of *Norwoodia gracilis* has a length of 11 mm. One of *N. saffordi,* 8 mm., and the largest cranidium of *N. tenera* has a length of 3.5 mm.

Genotype.—Norwoodia gracilis Walcott (pl. 27, figs. 2, *2a-b*).

Stratigraphic range.—Norwoodia saffordi: Upper Cambrian; Nolichucky shale.

Norwoodia gracilis, N. simplex, and *N. ponderosa:* Upper Cambrian; Conasauga shale.

Norwoodia tenera: Upper Cambrian; Weeks formation.

The above indicates that as far as known the genus had quite a prolonged existence in Upper Cambrian time.

Geographic distribution.—Eastern Tennessee, northeastern Alabama, and the House Range of western Utah.

Observations.—As known to me now, this genus is an unusual form that has hitherto escaped observation. It probably originated in the Atlantic or the Appalachian Sea, where it attained its greatest development; one species, *N. tenera,* is a somewhat modified species from the Cordilleran area of western Utah.

The species from Alabama were collected for me in the Coosa Valley by Dr. Cooper Curtice in 1885. The stratigraphy of the Conasauga formation is so difficult to work out, owing to faulting and flexing of the shales and interbedded limestones, that the exact stratigraphic position and vertical range of each species are unknown, but I think that the genus is of Upper Cambrian age and mostly of the horizon of the upper Conasauga formation in Georgia and Alabama, and the Nolichucky shale in Tennessee.

NORWOODIA GRACILIS, new species

Plate 27, figs. 2, *2a-g*

General form of dorsal shield a broad ellipse with large genal spines extending backward and outward nearly as far back as the pygidium.

Cephalon convex, roughly semicircular; marginal border strong, moderately convex, and continued into the strong genal spines; posterior border narrow, and separated from the fixed cheeks by a strong furrow that merges on each side near the genal angle into the strong intramarginal furrow of the cephalon. Glabella small, rounded conical, and marked by three pairs of short glabellar furrows on each side; a shallow occipital furrow defines a median occipital ring that has a long, slender spine extending back from the posterior center of the ring; frontal limb large and gently convex to the intramarginal furrow; intramarginal furrow usually clearly defined; frontal border flattened or slightly convex; postero-lateral limbs large and bearing a strong, slender, slightly curving spine at the genal angle.

Facial sutures as shown by figures 2, *2a, 2b,* plate 27.

Thorax with 9 segments; axial lobe convex, with a shallow transverse furrow on each side that serves to define a small tubercle next to the dorsal furrow; pleural lobes wide; a strong, straight furrow extends from the inner end of each segment nearly to the rounded end, which terminates in a falcate point sloping obliquely backward. A slender, long median spine (fig. *2f*) occurs on some of the axial lobes as in *N. tenera* (pl. 28, figs. *2d-e*).

Pygidium transverse; axial lobe divided into three rings and a terminal section by shallow transverse furrows; pleural lobes large and marked by four gently backward-curving furrows; border narrow.

The outer surface of the test appears to have been minutely granulated, but as all the specimens are preserved in a fine argillaceous shale, the outer surface is so injured by compression when the test was in a plastic condition that most of the irregularities, if such existed, have become obscured.

Dimensions.—One entire dorsal shield has a length of 11 mm. Some cranidia indicate that others may have had a length of 13 to 15 mm.

Observations.—Fragments of this species are abundant in the shale, but entire dorsal shields are rare. Figure 2, plate 27, has been restored in part from several specimens, of which only one injured example shows the entire cephalon, thorax, and pygidium.

The cranidium of *N. gracilis* differs in so many details from the other species that a comparison of the figures on plate 27 will enable the student to readily distinguish them.

Formation and locality.—Upper Cambrian: (90a, 91) Conasauga shale; Cedar Bluff, (92x, 145) Yancey's Bend and east of Turkeytown, all three on Coosa River; and (92xx) from brook on road from Lydia Angles to Blaine, Center Township, all in Cherokee County, Alabama.

Upper Cambrian: (124) Nolichucky shales overlying limestone which rests on the Rogersville shale, on Big Creek, southeast of Harlans Knob, 4 miles (6.4 km.) northeast of Rogersville, Hawkins County; and (106a) east of Shooks Ridge, in Bays Mountains, 10 miles (16.1 km.) southeast of Knoxville, Knox County, both in Tennessee.

Also Conasauga formation; (96c) shales 4 miles (6.4 km.) northwest of Rome, Floyd County, Georgia; and (358e) Birmingham City, Jefferson County, Alabama.

NORWOODIA PONDEROSA, new species

Plate 28, figs. 1, *1a-b*

This species is represented by a number of cranidia and associated pygidia. It differs from both *N. simplex* and *N. saffordi* (pl. 27) by its much larger genal spines and the narrow, strong frontal limb that appears to be without a defined frontal border. There are slight traces of two pairs of glabellar furrows and a faint defined occipital ring which has a short median spine with a strong base. Outer surface unknown.

Formation and locality.—Upper Cambrian: (90a) Conasauga shales; Cedar Bluff, Cherokee County, Alabama.

NORWOODIA SAFFORDI, new species

Plate 27, figs. 1, *1a-f*

This species differs from *Norwoodia gracilis* in the form of the frontal limb and border, fixed cheeks, and genal spines, and in having eight instead of nine thoracic segments.

The outer surface of the test appears to have been rather strongly granulated, as shown in the matrix of the species illustrated by figure 1*d*, plate 27.

Formation and locality.—Upper Cambrian: (103, 103a) Nolichucky shale. Second shale south of the ridge of sandstone "Town Knobs" on the road from Rogersville to Dodson Ford, Hawkins County; and (107a, 107b) shales in railroad cut in Bull Run Ridge, northeast of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, Knox County, both in Tennessee.

NORWOODIA SIMPLEX, new species

Plate 27, figs. 3, *3a-b*

This species differs in its cranidium, genal spines, and number of thoracic segments from *N. gracilis;* it has also a rounded appearance not seen in other species. The number of thoracic segments is eight, which is the same as in *N. saffordi*. The pygidium is nearly smooth, the furrows on the axial and pleural lobes being little more than incised lines.

Surface apparently finely granulated.

One entire dorsal shield has a length of 10 mm.

Formation and locality.—Upper Cambrian: (90a, 91) Conasauga shale; Cedar Bluff; also (145) bluffs of Coosa River, east of

Turkeytown, both in Cherokee County; and (138) shale in street northeast of Printuf House, Gadsden, Etowah County, all in Alabama.

Upper Cambrian: (124, 124a) Nolichucky shales overlying the limestone that is above the Rogersville shales, on Big Creek, southeast of Harlans Knob, 4 miles (6.4 km.) northeast of Rogersville, Hawkins County; also (117) Nolichucky shale; on the road north from Greeneville; and (117c) Buckingham Ford, Hollis Creek, 5 miles (8 km.) southeast of Greeneville, Greene County, all in state of Tennessee.

Also (138d) Conasauga shale; 3 miles (4.8 km.) west of Rome, Floyd County, Georgia.

NORWOODIA TENERA, new species

Plate 28, figs. 2, *2a-g*

In general form the dorsal shield of this species resembles that of *N. simplex* (pl. 27, figs. 3, 3*a*), but in details it is quite distinct. It has eight thoracic segments, the pleural lobes of which have a very narrow pleural furrow and slightly falcate ends; a slender median spine occurs on the third, fifth and seventh segments of the axial lobe, as shown by figure *2e,* plate 28.

Surface minutely granular with a few larger scattered granules on the cephalon, thoracic segments, and pygidium.

The largest entire specimen has a length of 3.5 mm.

Cranidium	1.5 mm.
Thorax	1.5 mm.
Pygidium	0.5 mm.

The largest cranidium in the collection has a length of 4 mm., which on the basis of the entire dorsal shield mentioned would give a total length of about 9.5 mm.

This small, neat species is abundant on two or three thin layers of shaly limestone of the Weeks formation.

Formation and locality.—Upper Cambrian: (30n) Weeks formation (1*c* of section),[1] also (30 o) (1*b* of section); north side of Weeks Canyon, 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 178.

Order OPISTHOPARIA Beecher

Genus AGRAULOS Corda

AGRAULOS STATOR, new species

Plate 36, fig. 6

Dorsal shield elongate, suboval in outline, moderately convex, and with a narrow, strongly defined axial lobe. Cephalon transversely semicircular, marginal rim narrow, genal angles rounded. The facial sutures cut the rounded genal angle and extend inward with a sigmoid curve to the base of the small eye lobes; in front of the eye lobes they curve outward a very little and then inward so as to cut the anterior rim of the cephalon on a line with the base of the eyes. Glabella truncato-conical, a little more than one-half the length of the cephalon, and marked by three pairs of shallow furrows separated by a narrow, faint median ridge; occipital furrow and ring narrow and clearly defined; fixed cheeks broad and merging anteriorly into the broad and long, moderately convex and rounded frontal limb; posteriorly the fixed cheeks merge into their postero-lateral limbs, which extend outward from the base of the palpebral lobe to the genal angles; a rather strong furrow outlines a narrow posterior border which merges into the outer rim of the cephalon at the genal angles; palpebral lobes small, situated nearly opposite the anterior end of the glabella and with a narrow palpebral ridge extending inward across the broad free cheek to the strong dorsal furrow about the glabella; free cheeks of medium size and separated from the fixed cheeks only by a small, short eye.

Thorax with 22 nearly transverse segments; axial lobe narrower than the pleural lobes, and with a well-defined node near the dorsal furrow on each side; pleural lobes with a strong, narrow furrow extending from near the dorsal furrow along the central part of the segment nearly to its rounded end; the anterior half of each segment has a smooth faceted surface which greatly facilitated the rolling up of the animal.

Pygidium small and marked only by one or two rings on the large axial lobe. Surface apparently minutely punctate.

Dimensions.—The relative size of the various parts of the dorsal shield is shown by the figures. The largest specimen has a length of 13 mm. for the cranidium and a total length of 38 mm.

Observations.—Comparing this species with the genotype, *Agraulos ceticephalus* Barrande, we find that it is similar in general form and in having a nearly smooth glabella, a large number of thoracic segments, and very small pygidium.

The species is unusually well represented. The first and best specimens were discovered by Mrs. Helena B. Walcott in 1907 at the south base of Mount Bosworth.

Formation and locality.—Lower Cambrian: Mount Whyte formation: (35c) drift blocks of siliceous shale supposed to have come from the Mount Whyte formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia; and (35m) (*Albertella* zone) 3 miles (4.8 km.) southwest of the head of Lake Louise, on east slope of Mount Whyte, Alberta.

Genus ACROCEPHALITES Wallerius

Acrocephalites Wallerius, 1895, Unders. Zonen med *Agnostus lævigatus* i Vestergötland, Lund, Sweden, pp. 52-53.

The following is the Swedish diagnosis of the genus:

Head agrees in form with *Conocoryphe.* Shell finely and regularly granulated. The glabella is slightly conical, bounded on all sides by deep furrows, provided with side furrows. In front of it is found a knob-shaped elevation. The anterior margin is broad with a deep intramarginal furrow. The fixed cheeks are broad. The palpebral lobes are of medium size, situated about in the middle of the cheeks. The facial sutures diverge considerably from the anterior margin to the palpebral lobes, from the latter onward they also continue outward, though somewhat less divergent, to the posterior edge. The movable cheeks are somewhat triangular, provided with spines at the angles. The other parts of the body are unknown.

As previously pointed out, *Acrocephalites* occupies about the same position to *Solenopleura, Conocephalites* (*Ptychoparia*), etc., as *Ctenocephalus* to *Conocoryphe.* Thus in *Acrocephalites,* too, it is the tubercle in front of the forehead that is the most striking characteristic. But furthermore, other characters are found here, which justify the establishment of the new genus. As only one species is at hand, it is impossible to determine definitely what characteristics are to be regarded as generic and what as specific; hence the dividing line between these becomes more or less arbitrary, and the two must accordingly complement each other.

Genotype.—*Solenopleura ? stenometopa* Angelin, 1851, Pal Scand., p. 28, pl. 19, fig. 4.

To the preceding description of the cephalon we may now add the following:

The boss or swelling in front of the glabella is confined to the area of the frontal limb and does not extend into the frontal border. The boss may vary greatly in the same species, as is shown by *A. haynesi* (pl. 24, figs. 4, 4*a*). The fixed cheeks may be narrow as in

A. stenometopus (pl. 24, fig. 1), or broad as in *A. americanus* (pl. 24, fig. 2). *Acrocephalites haynesi* (pl. 24, fig. 4) has a strong occipital spine.

Thorax with 17 to 25 segments of the type of those occurring in *Ptychoparia striata* (Emmrich), narrow, and with an almost straight pleural furrow that begins to narrow at the genal angle of the segment.

Pygidium small and with three or four narrow transverse rings that extend out on the pleural lobes as rather faint lines.

The surface of all known species of the genus is more or less strongly tuberculated.

Stratigraphic range.—The type species occurs in the *Agnostus lævigatus* zone of the Middle Cambrian. The American species occur as follows:

Acrocephalites vulcanus, Lower Cambrian.
Acrocephalites americanus, Middle Cambrian.
Acrocephalites aoris, Middle Cambrian.
Acrocephalites insignis, Middle Cambrian.
Acrocephalites ? majus, Middle Cambrian.
Acrocephalites multisegmentus, Middle Cambrian.
Acrocephalites tutus, Middle Cambrian.
Acrocephalites aster, Upper Cambrian.
Acrocephalites haynesi, Upper Cambrian.
Acrocephalites ? glomeratus, Upper Cambrian.

Geographic distribution.—Sweden, eastern United States in the states of Georgia, Alabama, and Vermont; western United States or Cordilleran area; in the Grand Canyon, Arizona; in Utah, and Montana.

Observations.—Wallerius illustrates with rather indifferent figures the cranidium and a free cheek of *A. stenometopus.* Through the kindness of Dr. Joh. Chr. Moberg I have had the opportunity of having an enlarged photograph made of the type specimen now in the collection of the University of Lund (pl. 24, fig. 1). The cranidium of *A. aster* (pl. 26, figs. 9, 9*a-c*) is closely related to that of *A. stenometopus,* but the nearest complete American species is *A. americanus* (pl. 24, figs. 2 and 3), which is fortunately represented by nearly entire specimens. The thorax has 27 segments and a small pygidium. The free cheek has a postero-lateral spine, in this respect being similar to the free cheek of *A. stenometopus* as illustrated by Wallerius. The thorax of *A. multisegmentus* has 25 or more segments (pl. 24, fig. 5*a*).

Acrocephalites ? majus (pl. 26, fig. 1) is doubtfully referred to *Acrocephalites.* It is slightly distorted, but there appears to have been a boss in front of the glabella that was crossed transversely by the narrow ridge that serves to separate the frontal limb and rim.

Comparison of genera.—Acrocephalites differs from *Alokistocare* (pl. 25) in having the boss in front of the glabella limited to the frontal limb, and in having a more or less tuberculated outer surface of the dorsal shield. The outer surface of *Alokistocare* is more or less punctate in the type species, *A. subcoronatum* (pl. 25, fig. 2). The typical species of each genus are readily distinguished, but there are such species as *Alokistocare labrosum* (pl. 25, figs. 5, 5*a*), which have the *Acrocephalites* form of cranidium with the punctate test surface of *Alokistocare.*

Comparing the cranidium of *Acrocephalites* with that of *Ctenocephalus exsulans* Linnarsson, we find that both have a tuberculated outer surface, rounded boss before the glabella within the frontal limb and similar form of glabella. The absence of free cheeks and eyes on the dorsal surface of *Ctenocephalus* is the essential difference between the two genera. In *Ctenocephalus* the advance of the facial suture and eye from the ventral to the dorsal surface appears to have been retarded during the entire development and growth of the cephalon.

Some of the forms referred to *Inouyia*[1] have a rounded boss on the frontal limb, but they differ so much in the appearance of the cranidium as a whole that, with the possible exception of *Inouyia titiana* (Walcott), there is little risk of confusing them with species of *Acrocephalites.*

Comparison of species.—The cranidium of *Acrocephalites stenometopus* (pl. 24, fig. 1) is nearer in form to that of *A. haynesi* (pl. 24, figs. 4, 4*a*) than to other species of the genus. It may have an occipital spine, but of this we have no positive information. *Acrocephalites tutus* (pl. 24, figs. 6, 6*a*) is also to be compared with the two mentioned species, but as the specimens representing it are flattened in the shale, the element of convexity must be restored when comparisons are made. *Acrocephalites insignis* (pl. 25, figs. 1, 1*a*) has the narrow fixed cheeks and frontal limb of *Acrocephalites stenometopus,* but owing to the compressed and more or less macerated condition of the test it is not possible to draw detailed comparisons.

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[1] Research in China, Carnegie Institution of Washington, Vol. III, 1913, pl. 14.

Acrocephalites americanus differs from *Acrocephalites insignis* (pl. 25, figs. 1, 1*a*) in its longer frontal limb and rim, proportionally broader fixed cheeks, and 17, instead of 21, thoracic segments. It is a much larger form than the genotype *A. stenometopus* (pl. 24, fig. 1), and differs in its longer and flatter frontal limb and less elevated boss on the frontal limb.

Acrocephalites ? aster (pl. 26, figs. 9, 9 *a-c*) has a frontal boss much like that of *A. stenometopus.*

Comparing the thorax of those species in which it is preserved, we have the following result:

Acrocephalites americanus (pl. 24, fig. 3), 18 thoracic segments.

Acrocephalites insignis (pl. 25, fig. 1*a*), 21 thoracic segments.

Acrocephalites multisegmentus (pl. 24, fig. 5*a*), 25 thoracic segments.

The three species all have very small pygidia, and the same type of thoracic segment and pleural furrow, although the pleural lobe is much narrower in *A. multisegmentus.*

The surface of the test of *A. multisegmentus* is more evenly granulated than that of *A. haynesi.*

Under previous conceptions of the genus most of the species now referred to *Acrocephalites* and *Alokistocare* would have been included in *Ptychoparia.*

ACROCEPHALITES AMERICANUS, new species

Plate 24, figs. 2, 2*a-b*, 3, 3*a-b*

This species is represented by beautiful specimens of the cranidium preserved as silicified casts of the test attached to siliceous nodules that occur in argillaceous shales. With one exception the specimens of the dorsal shield are from the shale; they are flattened by compression, and the fine surface characters of the silicified specimens are lost except for traces of the larger tubercles.

Thorax with 27 transverse, narrow segments; palpebral furrow narrow, rounded, and continued well towards the outer end of the segment. Pygidium small; axial lobe with three rings outlined by transverse furrows.

Surface marked by strong, scattered tubercles with a minutely granular surface between.

The largest cranidium has a length of 10 mm., and belonged to a dorsal shield that was about 40 mm. in length.

For comparison with other species, see notes under description of genus.

Formation and locality.—Middle Cambrian: (89x) Conasauga formation. In argillaceous shale and on and in siliceous nodules imbedded in the shale, Livingston, Coosa Valley, Floyd County, Georgia.

Also from (90) Conasauga shales; on Edwards farm, near Craigs Mountain, about 10 miles (16.1 km.) southeast of Center; (90x) about 5 miles (8 km.) east of Center; (112) shales in which siliceous nodules of 90x are imbedded; (16d) shales one mile (1.6 km.) east of Moshat and 5 miles (8 km.) east-southeast of Center on southeast bank of a small brook; and (95) shales on Cowan Creek, 0.5 mile (0.8 km.) above Center road ford, all in Coosa Valley, Cherokee County, Alabama.

ACROCEPHALITES AORIS, new species

Plate 26, figs. 3, *3a-b*

The cranidium of this species is much like that of *A. tutus* (pl. 24, figs. 6, *6a*). It differs in having narrower fixed cheeks; wider and stronger frontal border. The outer surface is finely tuberculated with minute depressions between them that indicate that the test is probably punctate. The form of the glabella is similar to that of *A. americanus* (pl. 24, figs. 2, *2a*), but other parts of the cranidium are quite different.

Formation and locality.—Middle Cambrian: (107d) Limestone; 1 mile (1.6 km.) north of Henrietta, Blair County, Pennsylvania.

ACROCEPHALITES ? ASTER, new species

Plate 26, figs. 9, *9a-c*

This is a very distinct species. The narrow median swelling on the frontal limb is much like that of *Acrocephalites stenometopus* (pl. 24, fig. 1), and unlike the boss on other species referred to the genus.

The occipital spine is broken off the specimen represented by figure *9b,* but it is finely shown as a cast in the shale matrix, where it has been removed by solution.

Formation and locality.—Upper Cambrian: (358e) Conasauga formation; buff-colored shales near street car barns, Birmingham City, Alabama; (107c) Maryville limestone, west base of Copper Ridge, 11 miles (17.7 km.) northwest of Knoxville, Knox County; and (15) Nolichucky shale, on Buckingham Ford road, 1.5 miles (2.4 km.) south of Greeneville, Greene County, both in Tennessee.

ACROCEPHALITES ? GLOMERATUS, new species

Plate 26, figs. 7, *7a*

This species, like *A. ? majus* (pl. 26, fig. 1), is represented by a cranidium that except for the boss on the frontal limb in front of the glabella would be referred to *Ptychoparia*. As in the case of *Acrocephalites haynesi* (pl. 24, figs. 4, 4*a*), there are associated cranidia that are similar to the one with the boss on the frontal limb except that they do not have the boss. The cranidia are preserved in a coarse ferruginous sandstone, and nothing remains of the test or its outer surface.

In view of the above statement the species is tentatively referred to *Acrocephalites*. The largest cranidium in the collection has a length of 20 mm.

Formation and locality.—Upper Cambrian: (340c) Dark reddish brown sandstone, Rawlins, Carbon County, Wyoming.

ACROCEPHALITES HAYNESI, new species

Plate 24, figs. 4, *4a-b*

This species is distinguished by strongly defined glabella, fixed cheeks, palpebral lobes, and frontal rim of the cranidium; also by the variability of the length of the frontal limb and the size of the boss in front of the glabella, accompanied by a coarsely granulated outer surface. It differs also in having a strong occipital spine.

The larger cranidia average 8 mm. in length.

This species is named after Mr. W. P. Haynes, who collected all the specimens known of it.

Formation and locality.—Upper Cambrian: Meagher limestone; on Pole Creek, a tributary of Cherry Creek, about 4 miles (6.4 km.) east of Madison River, Madison County, Montana.

Type in Museum of Comparative Zoölogy, Cambridge, Massachusetts.

ACROCEPHALITES INSIGNIS, new species

Plate 25, figs. 1, *1a-b*

All of the numerous specimens of this species were flattened and more or less macerated in the mud now forming the argillaceous shale in which they occur. The species is characterized by the narrow fixed cheeks, strong palpebral lobes, and the ridges into which they merge on the fixed cheeks. The width of the frontal limb and the size of its median boss are variable, but not as much so as in *A. haynesi* (pl. 24, figs. 4, 4*a*). There is no trace of an

occipital spine, but one specimen of the thorax has a median spine on the sixth and seventh segments, and another has a similar spine on the seventh, eighth, and ninth segments. The specimen illustrated has 21 thoracic segments. The surface is strongly granulated where well preserved.

Formation and locality.—Middle Cambrian: (112, 112a) Conasauga formation shales; about 5 miles (8 km.) east of Center, Cherokee County, Alabama.

ACROCEPHALITES ? MAJUS, new species

Plate 26, fig. 1

This species is represented by a single specimen of the cranidium that is flattened in an argillaceous shale. It was referred in my field notes to *Ptychoparia,* but the presence of the rounded boss on the frontal limb in advance of the glabella and coarse granulations on the outer surface serve to place it nearer *Acrocephalites* than to *Ptychoparia.* The granulated surface has been greatly obscured by the pressure to which the test has been subjected. In form the cranidium is similar to that of *A. tutus* (pl. 24, fig. 6) and compressed specimens of *A. americanus* (pl. 24, fig. 3*a*). A small median node occurs near the posterior margin of the occipital ring. The generic reference will remain doubtful until more and better preserved specimens are found.

Formation and locality.—Middle Cambrian: (4g) Wolsey shale; 5 miles (8 km.) east-northeast of Logan, and 1 mile (1.6 km.) north of forks of East and West Gallatin Rivers, Gallatin County, Montana.

ACROCEPHALITES MULTISEGMENTUS, new species

Plate 24, figs. 5, 5*a*

This small and very distinct species has narrow pleural lobes, strongly granulated surface, and 25 thoracic segments. The pleural furrows of the thoracic segments are very narrow, short, and rather insignificant when compared with those of *A. americanus* (pl. 24, fig. 3*a*), and less so with those of *A. insignis* (pl. 25, fig. 1*a*). The frontal border and rim are somewhat similar in form to those of *A. ? majus* except in the upward curvature of the frontal rim and the broader base of the glabella of *A. insignis.*

Formation and locality.—Upper Cambrian: (30n, 30 o) Weeks formation; 2 miles (3.2 km.) south of Millard Pass, House Range, Utah.

The horizon of 30 o is 170 feet above that of 30n in the stratigraphic section.

ACROCEPHALITES STENOMETOPUS (Angelin)

Plate 24, figs. 1, 1*a-b*

Solenopleura ? stenometopa ANGELIN, 1851, Pal. Scand., p. 28, pl. 19, fig. 4.
Acrocephalites stenometopus (Angelin) WALLERIUS, 1895, Unders. Zonen med *Agnostus lævigatus* i Vestergötland, p. 53.

The type specimen of this species, a cranidium, was sent to me from the Museum at Lund. It has the front rim, the greater part of the fixed cheeks, and the palpebral lobes broken off. The descriptions and illustrations of Wallerius were evidently added to by observations on other specimens.

A photograph of the type specimen is reproduced as figure 1, plate 24. All its characters are included in the description of the genus. The frontal limb is finely shown with its large, rounded central tubercle, but nothing is seen of the broad, anterior margin with a deep intramarginal furrow. These features were probably preserved on other specimens, as they are represented in the somewhat diagrammatic figures of Angelin and Wallerius.

The back side of the occipital ring is broken away in the specimen illustrated by figure 1, but it may have had a spine similar in character to that of *A. ? aster* (see pl. 26, figs. 9, 9*a*).

The description by Wallerius is very detailed, and I can add nothing for the use of the student except figures based on photographs of the specimens of the cranidium and free cheeks.

Formation and locality.—Middle Cambrian: (309n) *Agnostus lævigatus* zone, Gudhem and Djupadal, Skaraborg, Vestergötland, Sweden.

ACROCEPHALITES TUTUS, new species

Plate 24, figs. 6, 6*a*

The specimens of this species, like those of *A. americanus* preserving thoracic segments (pl. 24, figs. 3, 3*a*), have had the test softened and then compressed during the progress of the deposition and consolidation of the mud that formed the fine argillaceous shale, except that the compression and flattening were not so complete as for *A. americanus*. This is shown by the slight convexity of the species and the preservation of the granulated outer surface of the test.

Comparisons of this species with other species of the genus are given under observations on the genus.

Formation and locality.—Middle Cambrian: (141) Conasauga shale; on roadside near cemetery 1 mile (1.6 km.) northeast of Cave Spring, Floyd County, Georgia.

ACROCEPHALITES ? VULCANUS (Billings)

Plate 26, fig. 2

Conocephalites vulcanus BILLINGS, 1861, Rept. Geol. Vermont, Vol. 2, p. 952, fig. 357. (Original description and figure.)

Conocephalites vulcanus BILLINGS, 1863, Geol. Canada, 1863, p. 286, fig. 296. (Original description and illustration repeated.)

Conocephalites vulcanus BILLINGS, 1865, Pal. Fossils Canada, Vol. 1, p. 14, fig. 17. (Pamphlet of 1861 republished.)

Ptychoparia vulcanus (Billings) WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 198, pl. 26, figs. 4, 4*a*. (Republished Billings's description with comment and gives two figures.)

Ptychoparia vulcanus (Billings) WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 653, pl. 96, figs. 4, 4*a*. (Republished figures of 1886.)

Numerous more or less distorted casts of the cranidium of this species occur in a fine decomposed ferruginous and slightly calcareous sandstone. The matrix of the casts suggests a granulated surface, but this may result from its fine sandy character. Although the median boss on the frontal limb suggests a reference to *Acrocephalites,* the nearly smooth glabella and strong frontal rim point to some other genus that may be the representative of *Acrocephalites* in the Lower Cambrian formations. Both Mr. Billings and I failed to note the boss in front of the glabella. It is well defined in four specimens before me and quite small on two others.

The largest specimen of the cranidium has a length of 6 mm.

Formation and locality.—Lower Cambrian: (25) Sandstone just above Parkers Quarry, near Georgia; also (26) northeast of the Corman farm buildings, east of Highgate Springs, both in Franklin County, Vermont.

Genus ALOKISTOCARE Lorenz

Alokistocare LORENZ, 1906, Zeitschr. deutsch. geol. Gesellsch., Bd. 58, p. 62.

General form of the dorsal shield elongate-oval, narrowing gradually from the rather large cephalon to the small pygidium.

Cephalon with flattened marginal rim produced into spines at the genal angles. A low rounded boss occurs in front of the glabella that usually extends across the frontal limb onto the frontal rim so as to interrupt the furrow delimiting the two. On *A. labrosum* (pl. 25, figs. 5, 5*a*) the boss does not extend onto the frontal limb, and on *A. ? prospectense* (fig. 8) and *A. linnarssoni* (figs. 7, 7*a*) it only partially interrupts the indistinct frontal furrow. Palpebral lobe and eye of medium size; palpebral ridge strongly outlined across the relatively broad free cheek. Glabella defined by strong dorsal furrows

and marked by two or three pairs of short lateral furrows. Free cheeks of medium size.

Thorax with 17 to 19 narrow segments; axial lobe narrow; pleural lobes broad and with well-defined furrows that extend from the dorsal furrow outward to the backward-bending genal angle, where they narrow and disappear on the smooth slope of the outer section of the segment.

Pygidium small; axial lobe rather prominent and divided into about three rings by shallow, transverse furrows; pleural lobes small and marked by one or two transverse furrows.

Surface slightly roughened by shallow pits when enlarged by a strong lens.

Genotype.—*Conocephalites subcoronatus* Hall and Whitfield.

Stratigraphic range.—The genotype occurs in the lower portion of the Middle Cambrian. *Alokistocare althea, A. labrosum, A. linnarssoni, A. pomona,* and *A. prospectense* occur in the Middle Cambrian, and *A. althea* in the Upper Cambrian.

Geographic distribution.—Species of the genus occur in northern Arizona, central Nevada, western and northern Utah, and northern central Montana. It appears to have been limited to the interior seas of the western portion of North America.

Observations.—Dr. Lorenz compares the genus with his *Macrotoxus* and assigns to it *A. subcoronatum* (Hall and Whitfield) as the genotype, stating that it has long, bow-shaped eyes, punctate shell, and strong dorsal furrows about the glabella. He gained his impression of the long eyes (palpebral lobes) from Hall and Whitfield's illustration, but this was somewhat in error, as the palpebral lobes are not over one-sixth the length of the cranidium on the type specimen of the species now in the United States National Museum collections (pl. 25, fig. 2). Lorenz did not compare it with the closely related genus *Acrocephalites,* owing probably to the fragmentary specimens and incomplete illustrations of the latter genus. Comparison between the two genera is made in this paper under observations on *Acrocephalites.*

Alokistocare althea (pl. 25, fig. 4*a*) has 19 thoracic segments, and *A. pomona* (pl. 25, fig. 6), 18 thoracic segments. The segments are of the same type as those of *Ptychoparia striata*[1] and of *Acrocephalites americanus* (pl. 24, fig. 3*a*). The upward-curving frontal rim or border of the type species (pl. 25, fig. 2) occurs in most of

[1] Research in China, Carnegie Inst. of Washington, Vol. 3, Pub. No. 54, 1913, pl. 2, fig. 4.

the species now referred to the genus, but this character is not distinct in *A. labrosum* (pl. 25, fig. 5), *A. linnarssoni* (pl. 25, figs. 7, 7*a*), and *A. ? prospectense* (pl. 25, fig. 8). This may be owing partly to the conditions of preservation of the cranidia, as the associated free cheek of *A. linnarssoni* (pl. 25, fig. 7*a*) indicates a frontal rim not unlike that of *A. subcoronatum* (pl. 25, fig. 2).

As far as known to me, the outer surface of the test is smooth to the unaided eye and minutely roughened and apparently pitted or porous when examined with a strong lens.

ALOKISTOCARE ALTHEA, new species

Plate 25, figs. 3, 3*a*, 4, 4*a*

This species is represented by casts of several specimens of the cranidium that are preserved in a fine sandstone matrix. Nothing is known of the surface of the test, and only indistinct traces of the glabellar furrows are to be seen. The most nearly related cranidium is that represented by figures 4, 4*a*, plate 25, which differs in details of frontal rim and boss. The two forms are, however, closely related and may belong to the same species, the apparent differences being caused by the condition of preservation of the specimens. *Alokistocare althea* occurs in a fine sandstone matrix, and the variety in a sandy shale; the two beds are separated stratigraphically by 200 to 300 feet in thickness of sandy shale.

The specimens preserving the thorax (figs. 4, 4*a*) are from the Bright Angel shale, and the cranidia represented by figures 3 and 3*a* I collected in 1882 in the upper part of the Tapeats sandstone, about 200 feet below the horizon in the shale. The latter are casts preserved in a fine sandstone matrix.

Formation and locality.—Middle Cambrian: (74) Tapeats sandstone; at the head of Nunkoweap Valley, Grand Canyon of the Colorado River; and

Middle Cambrian: (74e) Bright Angel shale 100 feet (30.4 m.) above Tapeats sandstone; on west side of Cameron trail about 0.5 mile (0.8 km.) north of Indian Garden spring; south side Grand Canyon of the Colorado River, both from Coconino County, Arizona.

Collected and presented by Niles J. Cameron, 1911.

ALOKISTOCARE ? LABROSUM, new species

Plate 25, figs. 5, 5*a*

This species is represented by numerous specimens of the cranidium that have very strongly marked characters which serve to

make the species an intermediate form between *Conocephalites, Alokistocare,* and *Menomonia,* as far as comparison may be made with the cranidia. The frontal limb with its median boss and strong, rounded frontal rim suggests *Acrocephalites;* the broad fixed cheeks and slightly pitted outer surface, *Alokistocare,* and the strongly defined subtriangular glabella and occipital ring, *Menomonia.* Nothing more is known to me of the species than is shown by the illustrations. The test usually adheres to the matrix so as to show its interior surface; small fragments indicate that its outer surface is pitted or punctate, which may account for its adhesion to the matrix. The largest cranidium has a length of 12 mm.

Formation and locality.—Middle Cambrian: (5f) limestone interbedded in the Wolsey shale, Meagher County, on the road to Wolsey, about 4 miles (6.4 km.) south of the divide at the head of Sawmill Creek, and 11 miles (17.7 km.) south of Neihart, Little Belt Mountains, Cascade County, Montana.

ALOKISTOCARE LINNARSSONI (Walcott)

Plate 25, figs. 7, 7*a*

Ptychoparia ? linnarssoni WALCOTT, 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 47, pl. 9, figs. 18, 18*a*. (Description and illustrations of typical cranidia of the species.)

This is a fine species known only by its cranidium and free cheeks, which are well shown by the illustrations. The outer surface of the test has been more or less injured by weathering, but it indicates that it was originally minutely pitted or punctate. The character of the frontal margin of the cranidium is indicated by the flat rim of the associated free cheek, except that the rim thickens and is separated by a scarcely perceptible depression from the frontal limb. The largest cranidium in the collection has a length of 11 mm.

The most nearly related species, *A. ? prospectense,* occurs 3,000 feet lower down in the Eureka district section. They both have a rounded frontal limb and rim, but that of *A. ? prospectense* is shorter, and the palpebral lobes are larger and further back on the fixed cheeks.

Formation and locality.—Middle Cambrian: (58) shaly limestones in upper beds of the Secret Canyon shale; east side of New York and Secret Canyons, Eureka District, Eureka County, Nevada.

Upper Cambrian: (15j) Orr formation; southwest part Fish Spring Range; and (15t) near south end Fish Creek Range, both in Toole County, Utah.

ALOKISTOCARE POMONA, new species

Plate 25, fig. 6

General form elongate, with broad cephalon and thorax converging rather uniformly to the small, narrow pygidium. The cephalon is characterized by its relatively narrow glabella and fixed cheeks and broad free cheeks. One only of the species shows the median boss of the frontal limb crossing the transverse frontal furrow. The genal angles are produced into spines that extend backward some distance beyond the ends of the thoracic segments.

Thorax with 19 narrow segments; axial lobe strongly defined by its convexity; pleural lobes with the geniculation of the segments at about two-thirds the length of the segment, where rather strong straight pleural furrows bend backward and narrow to a sharp point.

Pygidium small, but details of structure unknown.

Surface, as shown by casts in fine argillaceous shale, slightly roughened by shallow pits.

The only nearly entire dorsal shield has a length of 6 mm. for cranidium, and 10 mm. for thorax.

Observations.—This fine species differs from other species referred to *Alokistocare* by its narrow fixed cheeks; broad free cheeks; narrow postero-lateral limb, and elongate, narrow glabella with its faint lateral furrows. With our present information it is placed under this genus pending further discovery of closely allied forms.

Formation and locality.—Middle Cambrian: (159f) Wolsey shale; below Sixteen Station in Sixteen Mile Canyon, Meagher County, Montana.

Collected and presented to U. S. National Museum by M. Collen.

ALOKISTOCARE ? PROSPECTENSE (Walcott)

Plate 25, fig. 8

Ptychoparia ? prospectensis WALCOTT, 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 46, pl. 9, fig. 20. (Description and illustration of type specimen of cranidium.)

Ptychoparia ? prospectensis WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 202, pl. 27, fig. 5. (Reprint of previous description and a poor reproduction of illustration.)

There is nothing to add to the original description of the type cranidium except to note that I now think that the "finely granulose" surface is produced by the minute ridges between shallow pits, and that the surface is characterized by shallow pits rather than fine

granulations. The resemblance to the cranidium of *A. linnarssoni* is mentioned in the note on that species.

Formation and locality.—Middle Cambrian: (52a) Prospect Mountain formation; shale interbedded in limestone 500 to 600 feet (152 to 182.8 m.) down northeast slope of Prospect Mountain, Eureka district, Eureka County, Nevada.

ALOKISTOCARE SUBCORONATUM (Hall and Whitfield)

Plate 25, fig. 2

Conocephalites subcoronatus HALL and WHITFIELD, 1877, Geol. Explor. Fortieth Par., Vol. 4, p. 237, pl. 2, fig. 1. (Original description and illustration.)

Ptychoparia subcoronata (Hall and Whitfield) WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 205, pl. 28, fig. 4. (Reprints original description and figure, and comments on species.)

Ptychoparia subcoronata (Hall and Whitfield) WALCOTT, 1891, Tenth Ann. Rept., U. S. Geol. Survey, p. 652, pl. 96, fig. 6. (Notes occurrence of species in Lower Cambrian of New York, and reproduces figures of Hall and Whitfield.)

There is little to add to the original description of Hall and Whitfield. Additional collections have afforded only the cranidia and shown that the outer surface is roughened slightly by shallow pits and possibly by punctæ.

The cranidium of *A. subcoronatum* may be compared with that of *A. althea* (pl. 25, figs. 3*a*, 4*a*), which is most nearly related to it.

Other species have some strong points of resemblance, such as wide fixed cheeks, boss in front of the glabella, flat, slightly upward-curving frontal rim, and small to medium-sized palpebral lobes.

The largest cranidium has a length of 8 mm.

Formation and locality.—Middle Cambrian: Type specimens from Ute limestone, base of Ute Peak, Wasatch Range; (31c, 54 o) Ute formation; 1*b* of section,[1] Blacksmith Fork Canyon, about 10 miles (16.1 km.) east of Hyrum, Cache County, Utah.

ALOKISTOCARE TICIDA, new species

Plate 26, figs. 6, 6*a*

This species is characterized by having a glabella about half as long as the cranidium; an elongate boss on the frontal limb crossing the frontal furrow; high and relatively narrow fixed cheeks; eyes posterior to the center of the cranidium; rather broad and upward-curving frontal rim, and rather short postero-lateral limbs. The glabella shows traces of three short furrows on each side.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 196.

Surface more or less roughened by small, shallow and deep pits, some of which result from weathering of the surface.

A cranidium 17 mm. in length has a width of about 14 mm. at the palpebral lobes.

The cranidium is similar to that of *A. pomona* (pl. 25, fig. 6) in having narrow fixed cheeks and palpebral lobes back of the center of the cranidium. It differs from *A. subcoronatum* in its narrow fixed cheeks, large size, and elevated palpebral lobes. Stratigraphically it occurs about 1,200 feet above *Alokistocare subcoronatum* in the Blacksmith Fork section.[1]

Formation and locality.—Middle Cambrian: (55s) Bloomington formation; *2b* of section;[2] about 9 miles (14.4 km.) above the mouth of Blacksmith Fork Canyon, and 15 miles (24 km.) east of Hyrum, Cache County, Utah.

Genus LONCHOCEPHALUS Owen

Lonchocephalus Owen, 1852, Rept. Geol. Wis., Iowa, Minn., p. 575. (Description.)

Lonchocephalus Hall, 1863, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., pp. 147, 160. (Quotes Owen's description and groups species belonging to several genera under *Lonchocephalus,* p. 160.)

Lonchocephalus Shumard, 1863, Trans. Acad. Sci. St. Louis, Vol. 2, p. 104. (Considers *Lonchocephalus chippewaensis* the type of the genus, but considers the genus synonymous with *Conocephalites.*)

Lonchocephalus Hall, 1867, Trans. Albany Inst., Vol. 5, p. 129. (Reprint of remarks of 1863.)

Lonchocephalus Owen, Miller, 1889, North Amer. Geol. and Pal., p. 555.

Original description by Owen. "In this small and singular genus the highly arched glabella is either undivided, or has only two very obscure furrows. A spine of greater or less length projects backwards from the base of the glabella, in the median line of the body over the thoracic segments (fig. 12, pl. 1A). The pygidium found associated in the same beds is semilunar, with little or no border, and has four segments on the axial lobe."

Following the above description is the description of *Lonchocephalus chippewaensis.* The generic description points clearly to this species, but the figure referred to is that of *L. hamulus.* The author also illustrates three cranidia of *L. chippewaensis* (pl. 1, figs. 6, 14; pl. 1A, fig. 9), which come within the generic description much more nearly than the cranidium of *L. hamulus.* The species most nearly related to *L. hamulus* is that illustrated and named by Owen *Crepicephalus ? wisconsensis* (pl. 1, fig. 13).

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 194-196.

[2] Idem, p. 194.

Dr. James Hall (1863, pp. 147, 148) considers *Lonchocephalus* a synonym of *Conocephalites,* although realizing that to unite *Crepicephalus* and *Lonchocephalus* with the typical form of *Conocephalites* is difficult (p. 148).

To the general description of Owen we may now add that the thorax has seven segments and that the dorsal shield is convex with an elongate oval outline. The only entire specimen has a length of 4.25 mm. Surface of the type species unknown, as all specimens are preserved as casts in a fine-grained sandstone. Specimens of *L. minutus, L. pholus, L. plena,* and *L. appalachia* have a more or less granulated surface with a shallow pitting in places.

Genotype.—*Lonchocephalus chippewaensis* Owen.

Stratigraphic range and geographic distribution.—*Lonchocephalus chippewaensis, L. minor,* and *L. sospita* occur in the Upper Cambrian Eau Claire formation, of Wisconsin and Minnesota; *L. bunus* in the Franconia formation, Minnesota; *L. minutus* in the Potsdam sandstone, eastern New York; *L. appalachia* in the Maryville limestone, Alabama; *L. pholus* and *L. plena* in the Weeks formation, western Utah, all Upper Cambrian.

Observations.—I think the species referred to *Lonchocephalus* should be characterized as having a short convex glabella, short frontal limb, and narrow frontal border, median spine on the occipital ring, six or seven thoracic segments, and a relatively large, well-developed pygidium with continuous border and strong axial lobe. As restricted, there are seven species now known to me: *L. chippewaensis* Owen, *L. minor* (Shumard), *L. minutus* (Bradley), *L. bunus* Walcott, *L. sospita* Walcott, *L. pholus* Walcott, and *L. plena* Walcott. The second species referred to *Lonchocephalus* by Owen, *L. hamulus,* is placed under the new genus *Saratogia.*

Of named and described genera *Lonchocephalus* is most nearly related to *Liostracus* Angelin, 1854.[1] With only the cranidia for comparison, the difference between them is in the frontal limb and rim, and the absence of well-defined glabellar furrows in *Liostracus.* The typical species of the latter occurs in the Middle Cambrian *Paradoxides oelandicus* zone of Sweden, and *Lonchocephalus* is an Upper Cambrian genus as far as known in America.

The specific name *Lonchocephalus fecundus* is mentioned by Safford in a list of fossils from the Knox shale,[2] but the species was not described or illustrated.

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[1] Pal. Scand., p. 27.

[2] Geology Tennessee, 1869, p. 212.

LONCHOCEPHALUS APPALACHIA, new species

Plate 35, figs. 6, *6a-e*

This is a fine large species more nearly related in some aspects to *Saratogia* than to *Lonchocephalus.* Its conical glabella with rounded front, short frontal limb, and strong frontal border all suggest *Lonchocephalus.*

The largest cranidium has a length of 15 mm. exclusive of the occipital spine.

Surface roughened by minute granulation that appears to be formed of very irregular ridges with shallow pits between them. On some places the granulation appears to predominate, and on others the pitting.

Formation and locality.—Upper Cambrian: (123a) Maryville limestone; 4 miles (6.4 km.) northeast of Rogersville, Hawkins County, Tennessee; (139a) Conasauga formation in thin layer of interbedded limestone, near Chepultepec, Jefferson County, Alabama.

LONCHOCEPHALUS BUNUS, new species

Plate 34, figs. 9, *9a*

This species differs from *L. chippewaensis, L. minor,* and *L. minutus* in its longer and more conical glabella and form of frontal rim. In the latter species the rim widens in front of the glabella, with the widening forming a blunt point extending inward towards the glabella; in *L. bunus* the inner side of the rim is uniformly curved and the outer side projects slightly, the rim narrowing laterally.

The largest cranidium in the collection has a length of 6 mm. Outer surface unknown.

Lonchocephalus bunus appears to be the representative of the genus in the Franconia formation.

Formation and locality.—Upper Cambrian: (99) Franconia formation; Minneiska, on the Mississippi River, near the line between Wabasha and Winona Counties, Minnesota.

LONCHOCEPHALUS CHIPPEWAENSIS Owen

Plate 34, figs. 3, *3a;* plate 37

Lonchocephalus chippewaensis OWEN, 1852, Rept. Geol. Wis., Iowa, Minn., p. 576, pl. 1, figs. 6, 14?; pl. 1A, fig. 9. (Description and illustration of the cranidium and pygidium.)

Conocephalites chippewaensis SHUMARD, 1863, Trans. St. Louis Acad. Sci., Vol. 2, p. 104. (Discusses species and considers it the type of the genus *Lonchocephalus.*)

Conocephalites minor HALL, 1863, Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 149, pl. 8, figs. 1-4. (Describes and illustrates typical forms of *L. chippewaensis* as *C. minor.*)

Conocephalites minor HALL, 1867, Trans. Albany Inst., Vol. 5, p. 132, pl. 3, figs. 1-4. (Reprint of paper of 1863.)

The type specimens of this species were from near Menomonie, Dunn County, Wisconsin, where later collections show the cranidia and pygidia in abundance, associated with *Crepicephalus iowensis* and *Menomonia calymenoides,* which are so characteristic of the Eau Claire formation. These two species are also associated with *L. chippewaensis* at Dresbach, opposite the mouth of Black River, where Shumard's specimens of *Conocephalites minor* came from. Shumard states that Owen's species, *Conocephalites chippewaensis* (= *Lonchocephalus*), is associated with his *C. minor.* I do not find them associated at either locality of *L. minor,* although the range of variation in the glabella of *L. chippewaensis* sometimes brings the shorter forms of the glabella close to the glabella of *C. minor.*

After examining a large series of specimens from various localities and studying the descriptions of *L. chippewaensis* by Owen and his illustrations, also those of Hall, I am convinced that Hall described and illustrated Owen's species under the impression that he was working with *L. minor* of Shumard. It is interesting to note that he does not refer to Owen's species *L. chippewaensis,* although the two forms are so much alike. He speaks of a specimen sent him by Shumard as being more rotund and with a proportionally shorter glabella. These characters constitute the differences between *L. minor* and *L. chippewaensis.* It would seem that Owen's species was overlooked at that time.

In the vicinity of Eau Claire the species is very abundant and ranges through the middle and upper beds of the Eau Claire formation; fine specimens are also abundant at Rock Falls, Dunn County.

Some of the cranidia have a slight longitudinal furrow on the frontal limb in front of the glabella and a tendency of the frontal rim to thicken and extend inward opposite the furrow.

By a fortunate find at St. Croix Falls, by Dr. Samuel Weidman, we now have an entire dorsal shield. This shows seven segments and clearly indicates that *Lonchocephalus* differs materially from other genera of the Olenidæ in having a convex cranidium with an occipital spine and a less number of thoracic segments. By using the somewhat abraded dorsal shield as a base and more perfect specimens of the cephalon and cranidium, a restoration has been made as shown by figure 3*a,* plate 34.

Lonchocephalus pholus (pl. 34, figs. 1, 1*a-b*) from western Utah is much like this species, and is its representative in the Cordilleran region.

Formation and locality.—Upper Cambrian: Eau Claire formation; (84) Dresbach, opposite the mouth of Black River, Winona County, Minnesota.

(82) On the bank of St. Croix River, at St. Croix Falls, Polk County; (82a) 25 feet (7.6 m.) above the water level near the Knapp, Stout & Co.'s building, Menomonie; (80) 0.66 miles (1.1 km.) southwest of the railway station, Menomonie; (134) banks of Red Cedar River opposite Menomonie; also (83a) Rock Falls, Dunn County; (78a and 98x) upper beds and (98) middle beds on Mount Washington, near Eau Claire, Eau Claire County; and (100a) Ettrick, Trempealeau County; all in Wisconsin.

LONCHOCEPHALUS MINOR (Shumard)

Plate 34, figs. 8, 8*a-b*

Conocephalites minor SHUMARD, 1863, Trans. St. Louis Acad. Nat. Sci., Vol. 2, p. 105. (Describes but does not illustrate species.)

Ptychoparia minor WALCOTT, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 91. (Species referred to *Ptychoparia*.)

Not *Conocephalites minor* HALL, 1863, Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 149, pl. 8, figs. 1-4.

Not *Conocephalites minor* HALL, 1867, Trans. Albany Inst., Vol. 5, p. 132, pl. 3, figs. 1-4.

Original description.—"Very small; glabella well defined by linear dorsal furrows, subcircular, much elevated above the cheeks, regularly convex, slightly longer than wide, marked on either side with two short, deep lateral furrows, which are directed obliquely backwards and reach not quite one-third the distance across; neck furrow linear, distinctly but not deeply impressed, sinuate, arched forward in the middle; neck segment short triangular, gently convex, not elevated, posterior angle terminating in a delicate acicular spine, which is prolonged backwards, its length unknown; front margin narrow, convex; cheeks rounded, having very delicate ocular ridges, which pass from the eyes in a short curve to reach the glabella, a short distance in advance of the anterior glabellar furrow.

"Length of head, 0.10 of an inch; length of glabella, 0.08.

"The glabella of this species has the form and convexity of *C.* (*Monocephalus*) *globosus* of Billings; but the latter is destitute of lateral furrows, and the neck segment is not triangular as in our species."[1]

[1] Shumard, Trans. St. Louis Acad. Nat. Sci., Vol. 2, p. 105.

Lonchocephalus minor differs from *L. chippewaensis* in having a proportionally shorter more rotund glabella, almost no frontal limb, and usually with a slight incurving of the frontal furrow toward the longitudinal axis of the glabella.

Formation and locality.—Upper Cambrian: (84) Eau Claire formation; Dresbach, opposite the mouth of Black River, Winona County, Minnesota.

This is the type locality of the species.

Also from (79x) Eau Claire formation; near flour mill on Beaver Creek, north of Galesville, Trempealeau County, Wisconsin.

LONCHOCEPHALUS MINUTUS (Bradley)

Plate 34, figs. 4, 4*a-g*

Conocephalites minutus BRADLEY, 1860, American Journ. Sci., 2d ser., Vol. 30, pp. 241-242, text figs. 1-3. (Detailed description of species, with note by E. Billings.)

Conocephalites minutus BILLINGS, 1860, *Idem,* pp. 242-243 (discussion of species), and pp. 337-338, text figs. 4*a-c*. (Additional data on species and further discussion of it.)

Conocephalites minutus BRADLEY, 1860, Can. Nat. and Geol., Vol. 5, pp. 420-421, and text figs. 1-3. (Reprint of paper in American Journal of Science noted above.)

Conocephalites minutus BILLINGS, 1860, *Idem,* pp. 422-425, and text figs. 4*a-c*. (Reprint of two notes in American Journal of Science noted above.)

Conocephalites minutus BRADLEY, 1861, Proc. American Assoc. Adv. Sci., Vol. 14, pp. 161-163, and text figs. 1-3. (Reprint of paper mentioned in first reference.)

Conocephalites minutus BILLINGS, 1861, *Idem,* pp. 163-166, and text figs. 4*a-c*. (Reprint of his two notes mentioned in the second reference.)

Conocephalites minutus HALL, 1863, Sixteenth Ann. Rept., New York State Cab. Nat. Hist., pp. 150-151, pl. 8, figs. 5-7. (Describes species and compares it with *C. minor*.)

Conocephalites minutus HALL, 1867, Trans. Albany Inst., Vol. 5, pp. 134-135, pl. 3, figs. 5-7. (Reprint of the preceding reference, with same figures.)

Ptychoparia minutus WALCOTT, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 91. (Refers to species and places it under *Ptychoparia*.)

Ptychoparia minuta WALCOTT, 1912, Smithsonian Misc. Coll., Vol. 57, No. 9, pp. 267-268, pl. 43, figs. 20-24. (Observations and illustrations.)

The study of the genus *Lonchocephalus* has led to its restriction to the form closely related to the type species *L. chippewaensis,* and this brings Bradley's species *minutus* under *Lonchocephalus*.

It is a small form represented by cranidia and pygidia, and it very closely resembles *L. chippewaensis*. One of the points of difference is its flattened frontal rim.

Formation and locality.—Upper Cambrian: Potsdam sandstone formation; (77) near the water level below the falls at the high bridge and also at several horizons in the section above, the highest point being 70-75 feet (21.3 to 22.9 m.) above the water, Ausable Chasm, near Keeseville, Essex County: (136a) in sandstone on a large brook at a point on the Mineville Railroad at the turning of the first Y near Port Henry, Essex County; (109) in sandstone 25 feet (7.6 m.) above the Archean, 1.5 miles (2.4 km.) south of Deweys Bridge on the Champlain Canal, Washington County; (110a) in sandstone a little above and east of the canal road, north end of town of Whitehall, Washington County; and (111) at the top of the Potsdam sandstone on Marble River, 1 mile (1.6 km.) south of Chateaugay, Franklin County; all in New York.

LONCHOCEPHALUS PHOLUS, new species

Plate 34, figs. 1, 1*a-b*

This species is known only from the cranidium. It differs from *L. chippewaensis* Owen and *L. minutus* (Bradley) in details of the glabella, fixed cheeks, and frontal limb. The cranidium is less convex and the occipital spine stronger than in the species mentioned.

The surface appears to be finely granulated as in *L. plena,* and also to have shallow pits scattered over it. The associated *L. plena* (pl. 33, fig. 2) has a shorter frontal limb and a convex and evenly rounded glabella.

The largest cranidium has a length of 6 mm. exclusive of the occipital spine.

Formation and locality.—Upper Cambrian: (30n) Weeks formation (1*c* of section),[1] also (30 o) (1*b* of section); north side of Weeks Canyon, 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

LONCHOCEPHALUS PLENA, new species

Plate 34, figs. 2, 2*a*

This species is represented by a cephalon and several cranidia. It differs from the associated *L. pholus* in the outline of the glabella, short frontal limb, and very narrow fixed cheek.

Surface of test apparently finely granulated and with shallow pits scattered irregularly on it.

The largest cranidium has a length of 3.5 mm. exclusive of the occipital spine.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 178.

Formation and locality.—Upper Cambrian: (30 o) Weeks formation (1*b* of section); north side of Weeks Canyon, 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

LONCHOCEPHALUS SOSPITA, new species

Plate 36, figs. 1, 1*a*

This species is represented by several small cranidia on a fragment of sandstone as shown by figure 5. The broadly rounded, nearly transverse front of the conical glabella, swollen frontal limb, and very narrow, thread-like frontal rim serve to distinguish it from other species of the genus. The largest cranidium has a length of 4 mm. Surface unknown.

Formation and locality.—Upper Cambrian: (339k) Eau Claire formation; near Winona, Winona County, Minnesota.

Specimen collected and presented to the United States National Museum by Mr. W. A. Finkelnburg, of Winona.

SARATOGIA, new genus

This genus is known only by the cranidia and free cheeks of the cephalon, fragments of the thoracic segments, and the pygidium.

The cranidium and free cheeks are not unlike those of *Crepicephalus iowensis* Owen and *Ptychoparia diademata* except that the fixed cheeks are narrow in *Saratogia* and there is a long spine on the occipital ring. The pygidia associated with *Saratogia calcifera* and *S. wisconsensis* and referred to those species are small and similar in type to the pygidium of *Ptychoparia kochibei*.[1]

The surface of the test of *Saratogia calcifera* is thickly studded with small, low granules.

The cranidia of the species referred to the genus indicate a length of from 40 to 45 mm. for the dorsal shield.

Genotype.—*Conocephalites calciferous* Walcott (1879, Thirty-second Ann. Rept. New York State Mus., pp. 129-130).

Stratigraphic range and geographic distribution.—*Saratogia calcifera* is found in the Upper Cambrian Hoyt limestone of New York; *S. arses* in the Nolichucky formation, Tennessee; *S. wisconsensis* and *S. volux* in the Eau Claire formation; *S. hamulus* and *S. hera* in the Franconia formation of Wisconsin, and *S. tellus* in the Middle Cambrian, Kiu-lung group of Shantung, China.

Observations.—The genus *Saratogia* differs from *Ptychoparia*[2] in the form of the glabella, narrow fixed cheeks, large eyes, and the

[1] Research in China, Carnegie Institution of Washington, 1913, Vol. 3, Pub. No. 54, pl. 12, figs. 5, 5*a*.

[2] Syst. Sil. du Bohême, Vol. 1, 1852, pl. 29, fig. 39.

concave curvature of the frontal limb and border. It has very little in common with *Lonchocephalus chippewaensis,* the genotype of the genus *Lonchocephalus,* under which all the species now included under *Saratogia* have been included.

The species now referred to *Saratogia* are:

Saratogia arses, n. sp. (pl. 35, figs. 4, 4*a-b*).
Saratogia aruno, n. sp. (pl. 35, figs. 5, 5*a-b*).
Saratogia calcifera (Walcott) (pl. 33, figs. 6, 6*a*).
Saratogia hamulus (Owen) [Sixteenth Ann. Rept. New York State Cab. Nat. Hist., 1863, pl. 7, figs. 43, 44].
Saratogia hera, n. sp. (pl. 35, figs. 3, 3*a-b*).
Saratogia tellus (Walcott) [Research in China, Carnegie Institution of Washington, No. 3, Vol. 54, 1913, pl. 14, fig. 1].
Saratogia volux, n. sp. (pl. 34, fig. 3).
Saratogia wisconsensis (Owen) (pl. 34, figs. 5, 5*a-c*) [See Hall, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., 1863, pl. 7, figs. 39-41; pl. 8, figs. 22, 23, 24, 27, 28. Walcott].

The occurrence of *Saratogia hamulus* (Owen) in the Yellowstone National Park is quite probable, but not proven by reliable specimens.[1]

SARATOGIA ARSES, new species

Plate 35, figs. 4, 4*a-b*

This is a small species represented by a cranidium about 4 mm. in length exclusive of the occipital spine. It differs from the somewhat similar species *S. aruno* (pl. 35, fig. 5) and *S. wisconsensis* (pl. 34, fig. 5) in form of glabella and in the greater convexity of the glabella. The outer surface of the test appears to be nearly smooth.

The occurrence of this species in one of the thin gray limestone layers in the Nolichucky shale is interesting, as it serves to connect the Upper Cambrian fauna of the Appalachian region and that of the upper Mississippian area.

Formation and locality.—Upper Cambrian: (173) Nolichucky formation; Maryville, Blount County, Tennessee.

SARATOGIA ARUNO, new species

Plate 35, figs. 5, 5*a-b*

This small species is represented by a cranidium that is very much like that of *Saratogia wisconsensis* (pl. 34, fig. 5), and it may be that with more and better specimens it will be decided that the two are specifically identical.

[1] Monogr. 32, U. S. Geol. Survey, 1899, p. 461.

The cranidium illustrated has a length of 3 mm. exclusive of the occipital spine, and occurs in a fine argillaceous shale.

Formation and locality.—Upper Cambrian: (128) Conasauga formation; 1.5 miles (2.4 km.) southwest of Cleveland, Bradley County, Tennessee.

SARATOGIA CALCIFERA (Walcott)

Plate 34, figs. 6, 6*a-e*

Conocephalites calciferous WALCOTT, 1879, Thirty-second Ann. Rept. New York State Mus., pp. 129-130. (Description of species.)

Ptychoparia calcifera (WALCOTT), 1886, Bull. U. S. Geol. Surv., No. 30, p. 21. (Name in list of species.)

Ptychoparia calcifera (Walcott) DWIGHT, 1887, Trans. Vassar Bros. Inst., Vol. 4, pp. 207-208. (Species mentioned in text.)

Ptychoparia calcifera (Walcott) LESLEY, 1889, Geol. Surv. Pennsylvania, Rept. P 4, Dictionary of Fossils, Vol. 2, p. 831. (Text fig. 1 reproduced from drawing sent him by Walcott.)

Ptychoparia calcifera WELLER, 1903, Geol. Surv. New Jersey, Rept. on Pal., Vol. 3, The Paleozoic Faunas, pl. 1, fig. 14. (Illustrates a fragment doubtfully referred to this species.)

Lonchocephalus calciferus (WALCOTT), 1912, Smithsonian Misc. Coll., Vol. 57, No. 9, pp. 270-272, pl. 43, figs. 7-10. (Repeats earlier description and adds further observations.)

This species has been recently described in this series of papers. The illustrations are reproduced for comparison with the type species of the genus *Lonchocephalus* (pl. 34, figs. 3, 3*a-b*).

Saratogia calcifera is made the genotype of *Saratogia* on account of its being in a much better state of preservation than other species referred to the genus.

Formation and locality.—Upper Cambrian: Hoyt limestone; (76) arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County; (76a) in a railroad quarry, 1 mile (1.6 km.) north of Saratoga Springs, Saratoga County; and in arenaceous limestone, 2 miles (3.2 km.) south of Poughkeepsie, Dutchess County; all in New York.

SARATOGIA HERA, new species

Plate 35, figs. 3, 3*a-b*

This is essentially similar to *S. wisconsensis* with a glabella of the *Conaspis shumardi* form. Only the cranidia are preserved, along with scattered thoracic segments bearing a long, slender, backward-extending spine on the axial lobe.

Surface unknown. The largest cranidium has a length of 14 mm. exclusive of the occipital spine.

Formation and locality.—Upper Cambrian: (98a) Franconia formation; Marine Mills, Washington County, Minnesota.

SARATOGIA VOLUX, new species

Plate 35, figs. 2, *2a*

This species is known only by the cranidium. It is associated with *Lonchocephalus chippewaensis* Owen, but the nearest related form is *Saratogia wisconsensis* (Owen). It differs from the latter in having a more conical glabella, shorter frontal limb, proportionally wider frontal border, and shorter median spine on the occipital ring. The palpebral lobes are about one-fourth the length of the cranidium.

Surface unknown. The largest cranidium has a length of 8 mm. exclusive of the occipital spine.

Formation and locality.—Upper Cambrian: (78a) Eau Claire formation; upper quarry on Mount Washington, near Eau Claire, Eau Claire County, Wisconsin.

SARATOGIA WISCONSENSIS (Owen)

Plate 34, figs. 5, 5*a-c*

Crepicephalus ? wisconsensis Owen, 1852, Rept. Geol. Surv. Wis., Iowa, Minn., pl. 1, fig. 13. (Illustrates a cranidium.)

Conocephalites wisconsensis Hall, 1863, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., p. 164, pl. 7, figs. 39-41 (42); pl. 8, figs. 22-24, 27, 28; p. 147 (*obiter*). (Describes and illustrates species.)

Conocephalites wisconsensis Shumard, 1863, Trans. Acad. Sci. St. Louis, Vol. 2, p. 103. (Comments upon and gives additional information, but not as complete as Hall.)

Dikelocephalus latifrons Shumard, 1863, *Idem*, p. 101. (Describes a broken cranidium subsequently referred to *Conocephalites wisconsensis* by Hall.)

Conocephalites latifrons Hall, 1863, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., p. 122 (gen. ref.), p. 165, pl. 7, fig. 40. (Refers species to *C. wisconsensis,* and illustrates type specimen of Shumard.)

Conocephalites wisconsensis Hall, 1867, Trans. Albany Inst., Vol. 5, p. 130 (*obiter*), p. 151, pl. 2, figs. 39-41; pl. 3, figs. 23-24, 27, 28. (Reprint of description and illustrations of 1863.)

Anomocare wisconsensis (Hall) Dames, 1883, Richthofen's China, Berlin, Vol. 4, p. 15 (gen. ref.). (Refers Hall's *Conocephalites wisconsensis,* 1863, pl. 7, fig. 39; pl. 8, figs. 22-24, 27, 28, to *Anomocare.*)

Conocephalites wisconsensis (Owen) Chamberlin, 1883, Geol. Wis., Vol. 1, p. 131. (Reproduces figures of cranidium and free cheek after Hall, 1863.)

Ptychoparia (*Lonchocephalus*) *wisconsensis* (Owen) WALCOTT, 1899, Monogr. U. S. Geol. Surv., Vol. 32, Pt. 2, p. 461, pl. 64, figs. 1, 1*a-b*. (Notes occurrence in Wyoming, and illustrates. By error a pygidium of *Ptychoparia ? diademata* Hall is referred to this species, pl. 64, fig. 1*c*, and a cranidium of *Saratogia hamulus* (Owen), fig. 1*b*.)

Ptychoparia (*Lonchocephalus*) *wisconsensis* (Owen) Walcott, GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 277. (Notes occurrence of species.)

This species is known only by the cranidium, free cheeks, and possibly pygidium. In the Franconia formation of Wisconsin and Minnesota it occurs in the form of casts in fine-grained sandstone, and its outer surface is not preserved, and the same is true of the specimens from the Yellowstone National Park, which are slightly eroded as they occur on the limestone slabs. *Saratogia wisconsensis* differs from *S. calcifera* in many details of the cranidium, notably in the frontal limb and rim. It is quite unlike *S. hamulus* (Hall).

Formation and locality.—Upper Cambrian: (151e) Gallatin limestone; north side of Soda Butte Creek, below saddle on ridge between Pebble Creek and Soda Butte Creek, Crowfoot section, northeastern corner of Yellowstone National Park, Wyoming.

Also (79) Eau Claire formation; Hudson, St. Croix County; (**99a**) Franconia formation; near Pilot Knob, Adams County; (**83**^{3}) Trempealeau, Trempealeau County; all in Wisconsin.

Also Franconia formation; (97) Reeds Landing, foot of Lake Pepin, Wabasha County; and (339g) near Winona, Winona County; both in Minnesota.

And (**86c**) Eau Claire formation; Lansing, Allamakee County, Iowa. Southeast of city at low-water mark.

This species occurs at other localities in Wisconsin and Minnesota, but at present I do not have specimens before me for identification except from those given above.

Family CERATOPYGIDÆ

Genus CREPICEPHALUS Owen

Crepicephalus OWEN, 1852, Rept. Geol. Surv. Wis., Iowa, Minn., p. 576, pl. 1, fig. 8, tab. A1, figs. 10, 16, 18. (Describes genus and refers to figures of cranidium and pygidium of the species *C. iowensis*.)

Crepicephalus HALL, 1863, Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 147. (Reprints Owen's description, and comments on genus. Refers species *C. iowensis* to *Conocephalites*.)

Crepicephalus SHUMARD, 1863, Trans. Acad. Sci. St. Louis, Vol. 2, p. 103. (Considers *Crepicephalus* as identical with *Conocephalites*.)

Crepicephalus HALL, 1867, Trans. Albany Inst., Vol. 5, p. 130. (Reprint of paper of 1863.)

Crepicephalus HALL and WHITFIELD, 1877, U. S. Geol. Expl. 40th Parl., Vol. 4, p. 209. (Discuss *Crepicephalus* as a possible synonym of *Loganellus* Devine, and refer a new species of *Ptychoparia* named *haguei* to *Crepicephalus* (*Loganellus*), also the new species *nitidus, granulosus, maculosus, unisulcatus, simulator, anytus,* and *angulatus,* none of which belong to *Crepicephalus.*)

Crepicephalus WALCOTT, 1884, Bull. U. S. Geol. Surv., No. 10, p. 35. (Calls attention to placing of species referred to *Crepicephalus* (*Loganellus*) by Hall and Whitfield under *Ptychoparia* and remarks on *Crepicephalus.*)

Crepicephalus WALCOTT, 1886, *Idem,* No. 30, p. 206. (Quotes Owen's description and remarks, and concludes that *Dikelocephalus ? iowensis* should be taken as the genotype.)

Crepicephalus Owen, MILLER, 1889, North Amer. Geol. and Pal., p. 540. (Gives a generic description and refers to *C. iowensis* Owen as the type of the genus, also includes many species of other genera under *Crepicephalus.*)

Crepicephalus VOGDES, 1890, Bull. U. S. Geol. Surv., No. 63, p. 105. (Concludes that Owen described a true *Ptychoparia* and not a new generic form.)

Crepicephalus VOGDES, 1893, Cal. Acad. Sci., Occ. Pap., Vol. 4, p. 293. (Reprint of comments of 1890.)

Crepicephalus WALCOTT, 1899, Monogr. U. S. Geol. Surv., Vol. 32, Pt. 2, p. 459. (Gives reasons for using *C. iowensis* as the type of the genus, and illustrates an entire dorsal shield of an allied species, *C. texanus* (pl. 55, fig. 5).)

Crepicephalus Owen, GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 283. (Brief diagnosis of genus.)

The cephala of the species referred to *Crepicephalus* vary in details, but all have the elongate glabella with sides converging towards the front, and two or three pairs of more or less distinctly defined short glabella furrows; the occipital ring may have a strong median spine, *C. tripunctatus magnispinus,* or a minute node at its center, *C. iowensis.* The frontal limb may be short and convex, *C. iowensis,* or broad and depressed, *C. texanus;* the frontal furrow may be narrow and simple, *C. iowensis,* or broad and marked by three relatively large pits; the frontal border may be narrow and wire-like, *C. iowensis,* or broad and flattened, *C. texanus.* In all species the eyes are of medium size, centrally placed, and with a narrow ridge crossing the fixed cheek from the palpebral lobe to the dorsal furrow near the anterior end of the glabella.

The free cheeks all have a rather strong genal spine. The course of the facial suture is similar to that of *Ptychoparia.*

The thorax has from 12 to 14 transverse segments; pleural furrows well defined, and termination of pleural lobes of each segment slightly falcate.

The pygidia may be arranged in two groups: First, the *C. iowensis* group, in which the postero-lateral margin of the pygidium extends backward on each side from a broad base into a sharp narrow spine. Second, the *C. texanus* group, in which the postero-lateral spines are long, slender, and attached to the side of the pleural lobe above the margin. The latter appears to be the oldest form, as it occurs with *C. augusta* and *C. liliana* (pl. 29) of the upper beds of the Lower Cambrian, and also with the Middle Cambrian species of China, *C. convexus*.[1] One of the Chinese species, *C. damia,* has an associated pygidium[2] that is similar in appearance to the pygidium of *C. texanus*.

The surface of the *C. iowensis* group of species is smooth to the unaided eye, but slightly roughened by fine pitting when seen with a strong lens. The *C. texanus* group of species all have a more or less decided granulation. The test of all known species of the genus in which it is preserved is pitted and apparently punctate.

The various species now referred to *Crepicephalus* may be grouped as follows:

Crepicephalus iowensis group: Test nearly smooth, probably punctate, frontal furrow of cranidium narrow and simple; pygidium transverse with border extended into broad-based sharp postero-lateral spines. Species: *C. iowensis* (pl. 29), *C. camiro* (pl. 32), *C. convexus* (China), *C. coosensis* (pl. 32), *C. dis* (pl. 32), *C. magnus* (China), *C.* undt. spp. (pl. 32, figs. 4 and 4*a*).

Crepicephalus texanus group: Test granulated, probably punctate; frontal furrow of cranidium usually broad and strong, with three marked pits in front of the glabella; pygidium slightly transverse with a narrow, long spine coming out of the pleural lobe on each postero-lateral side. Species: *C. texanus* (pl. 30), *C. comus* (pl. 31), *C. coria* (pl. 33), *C. damia* (China), *C. texanus danace* (pl. 29), *C. texanus elongatus* (pl. 29), *C. thoosa* (pl. 31), *C. tripunctatus* (pl. 33), *C. tripunctatus magnispinus* (pl. 33), *C. tumidus* (pl. 31).

The species *C. tripunctatus* and variety *magnispinus* differ from all other known species of the genus in having a strong occipital spine.

Genotype.—Dikelocephalus ? iowensis Owen.[3]

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[1] Research in China, Carnegie Institution of Washington, Vol. 3, 1913, pp. 140-142, pl. 13, fig. 16*b*.

[2] *Idem,* pl. 13, fig. 14*b*.

[3] Rept. Geol. Surv. Wis., Iowa, Minn., 1852, p. 575, pl. 1, fig. 4; pl. 1A, fig. 13.

Dr. Owen describes the genus *Crepicephalus* (1852), but does not mention a species as the type species or apply the name to the form which he describes generically. He refers in his generic description to several figures; the first is figure 16 of plate 1A. This has in it two pygidia and two cranidia of *C. iowensis*. He also refers to figures 10 and 18 of the same plate, both of which have a cranidium of *C. iowensis* on the rock.

The associated pygidia that he refers to and illustrates by figure 8 of plate I and figure 16 of plate IA both belong to *C. iowensis*. Apparently by error, Dr. Owen placed the species *C. iowensis* under the genus *Dikelocephalus* and in the description of the plate as *Dikelocephalus ? iowensis*.

In view of the references to the figures in the generic description, and evident error in referring the species *iowensis* to the genus *Dikelocephalus*, the cranidium of which it does not resemble in any respect, I think we should assume without question that the species *iowensis* is the type of the genus *Crepicephalus*.

It is also to be noted that in the description of figure 13, plate I, by Owen, the species *wisconsensis* is referred with a query (?) to the genus *Crepicephalus*. No reference, however, is made to that species in the text.

Messrs. Hall and Whitfield, in describing Cambrian trilobites from Utah and Nevada, discussed the genus *Conocephalites* and revived *Crepicephalus* as a subgenus equivalent to *Loganellus* of Devine. They did not, however, describe the genus *Crepicephalus*, but referred a number of species to it which possess more or less distinctly marked "slipper-shaped" glabellæ. Prof. Whitfield subsequently used the genus in his description of *Crepicephalus* (*Loganellus*) *montanensis*[1] in the Paleontology of the Black Hills of Dakota.[2] But later (1882) he omitted reference to *Loganellus* in describing *Crepicephalus onustus*.[3]

Stratigraphic range.—Lower Cambrian: Upper beds: *C. augusta*, *C. liliana*.

Middle Cambrian: *C. convexus*, *C. damia*, *C. magnus*, from China; *C. coosensis*, from Alabama.

Upper Cambrian: *C. iowensis*, *C. camiro*, *C. comus*, *C. coria*, *C. texanus*, *C. texanus danace*, *C. texanus elongatus*, *C. thoosa*, *C. tripunctatus*, *C. tripunctatus magnispinus*, *C. tumidus*, *C. unca*, *C. unzia*, *C. upis*, *C.* undt. spp.

[1] Bull. U. S. Geol. Survey, No. 30, 1886, p. 141.

[2] Rept. Geology and Resources of the Black Hills (Jenney), 1880, pp. 341-343.

[3] Geol. Wisconsin, Vol. 4, 1882, p. 182.

Geographic distribution.—Appalachian Province: Virginia to Alabama.

Mississippian Province: Wisconsin, Texas.

Cordilleran Province: Montana, northern Wyoming, Utah.

China: Southwestern Manchuria, Shantung. Australia: Gippsland, Victoria. Identified from a pygidium.[1]

Observations.—This is a very valuable genus to the stratigraphic geologist, owing to the wide distribution of several of the species, notably *C. texanus, C. thoosa,* and *C. tripunctatus.* With more thorough and systematic collecting, it will undoubtedly furnish very important data for the subdivision of the various formations in which the species and varieties occur. The persistence of a considerable range of variation among the cranidia of *C. texanus* at the several localities where the species occurs serves to strengthen the identification of that species in Texas, Arizona, Wyoming, and Alabama.

The genus falls into the family Ceratopygidæ.[2] The relatively large pygidium with its postero-lateral spines is characteristic of other genera referred to the family.

The species now referred to *Crepicephalus* are:

Crepicephalus augusta Walcott (pl. 29, figs. 6, 6*a-b*).
Crepicephalus camiro Walcott (pl. 32, figs. 2, 2*a*).
Crepicephalus comus Walcott (pl. 31, figs. 3, 3*a*).
Crepicephalus convexus Walcott [The Cambrian Faunas of China, Walcott, Carnegie Institution of Washington, Vol. 3, Pub. No. 54, 1913, p. 140, pl. 13, figs. 16, 16*a-b*].
Crepicephalus coosensis Walcott (pl. 32, figs. 3, 3*a-f*).
Crepicephalus coria Walcott (pl. 33, figs. 3, 3*a-g*).
Crepicephalus dis Walcott (pl. 32, figs. 1, 1*a-c*).
Crepicephalus damia Walcott [The Cambrian Faunas of China, *supra,* p. 141, pl. 13, figs. 14, 14*a-b*].
Crepicephalus etheridgei Chapman [Proc. Royal Soc. Victoria, n. s., Vol. 23, p. 319, pl. 58, fig. 8. Locality, Dolodrook River, N. E. Gippsland, Victoria].
Crepicephalus iowensis (Owen) (pl. 29, figs. 1, 2, 2*a-f*).
Crepicephalus liliana Walcott (pl. 29, figs. 5, 5*a-c*).
Crepicephalus texanus (Shumard) (pl. 29, fig. 7; pl. 30, figs. 1-4, 4*a*).
Crepicephalus texanus danace Walcott (pl. 29, figs. 3, 3*a*).
Crepicephalus texanus elongatus Walcott (pl. 29, figs. 4, 4*a*).
Crepicephalus thoosa Walcott (pl. 31, figs. 1, 1*a-k*).
Crepicephalus tripunctatus (Whitfield) (pl. 33, figs. 1, 1*a*).
Crepicephalus tripunctatus magnispinus Walcott (pl. 33, figs. 2, 2*a-c*).
Crepicephalus tumidus Walcott (pl. 31, fig. 2).

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[1] *Crepicephalus etheridgei* Chapman.

[2] Text-book of Palæontology, Zittel-Eastman, 1913, Vol. 1, p. 717.

Crepicephalus unca Walcott (pl. 35, figs. 1, 1*a-c*).
Crepicephalus unzia Walcott (pl. 34, figs. 7, 7*a*).
Crepicephalus upis Walcott (pl. 33, figs. 4, 4*a-d*).
Crepicephalus undt. spp. (pl. 32, figs. 4, 4*a*).

The American species previously referred to *Crepicephalus* and now referred to other genera are:

Crepicephalus centralis Whitfield = *Anomocarella oweni* (Meek and Hayden).
Crepicephalus gibbsi Whitfield = *Ptychoparia* Corda.
Crepicephalus (?) *miniscaensis* Owen = *Ptychaspis* Hall.
Crepicephalus onustus Whitfield = *Anomocarella* Walcott.
Crepicephalus roanensis Safford = Unpublished species Walcott.
Crepicephalus similis Safford = Unpublished species Walcott.
Crepicephalus tennesseensis Safford = Unpublished species Walcott.
Crepicephalus ? wisconsensis Owen = *Lonchocephalus* Owen.
Crepicephalus (*Bathyurus?*) *angulatus* Hall and Whitfield = *Ptychoparia* (*Emmrichella*) Walcott.
Crepicephalus (*Loganellus*) *granulosus* Hall and Whitfield = *Inouyia* Walcott.
Crepicephalus (*Loganellus*) *haguei* Hall and Whitfield = *Ptychoparia* Corda.
Crepicephalus (*Loganellus*) *maculosus* Hall and Whitfield = *Ptychoparia* Corda?
Crepicephalus (*Loganellus*) *montanensis* Whitfield = *Ptychoparia* Corda.
Crepicephalus (*Loganellus*) *nitidus* Hall and Whitfield = *Ptychoparia* Corda.
Crepicephalus (*Loganella*) *planus* Whitfield = *Ptychoparia* Corda.
Crepicephalus ? (*Loganellus*) *quadrans* Hall and Whitfield = *Ptychoparia* Corda.
Crepicephalus (*Loganellus*) *simulator* Hall and Whitfield = *Inouyia* Walcott.
Crepicephalus (*Loganellus*) *unisulcatus* Hall and Whitfield = *Ptychoparia* Corda?

CREPICEPHALUS AUGUSTA Walcott

Plate 29, figs. 6, 6*a-b*

Crepicephalus augusta WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 208, pl. 28, figs. 2, 2*a-b*. (Description and illustration of cranidium and pygidium.)

Crepicephalus augusta WALCOTT, 1891, Tenth Ann. Rep. U. S. Geol. Survey, p. 653, pl. 96, figs. 9, 9*a-b*. (Republishes illustrations of 1886.)

Crepicephalus augusta (Walcott), GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 283, fig. 1585. (Described and figured.)

A detailed description of the specimen representing this species was published in 1886, and nothing has been added to it since. The illustrations are given in this paper in order that the American species referred to *Crepicephalus* may be brought together for comparative study.

Formation and locality.—Lower Cambrian: (30) Limestone 8 miles (12.8 km.) north of Bennetts Spring, on the west slope of the Highland Range; (31a) limestones of Pioche formation, just above the quartzite on east side of anticline, near Pioche, both in Lincoln County, Nevada.

CREPICEPHALUS CAMIRO, new species

Plate 32, figs. 2, 2*a*

This is the Appalachian representative of *C. iowensis.* It differs in its small glabella and broad frontal limb of the cranidium, and the associated pygidium has about six faintly defined rings and a terminal section on the axial lobe. The outline of the postero-lateral borders of the pygidium also differs materially by sloping inward, and the two spines are shorter and nearer together proportionally with regard to the size of the pygidium.

Surface of test minutely pitted or apparently punctate under strong lens, but smooth to the unaided eye.

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, on Beaver Creek, Sevier County, 18 miles (28.8 km.) east-northeast of Knoxville; and (107) Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, both in Tennessee.

CREPICEPHALUS COMUS, new species

Plate 31, figs. 3, 3*a*

This species is represented by cranidia and associated pygidia. The glabella is tumid as in *C. tumidus,* but the frontal limb is little more than a narrow convex extension of the convex fixed cheeks grading into the broad frontal groove which lies within the very prominent, rounded frontal border. The three pits in the frontal furrow are nearly round, and large for the size of the cranidium.

Surface finely granulated and test apparently punctate.

The largest cranidium in the collection has a length of 17 mm.

The associated pygidia (fig. 3*a*) are much like those of *C. thoosa* (figs. 1*f-k*).

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, on Beaver Creek, Sevier County, 18 miles (28.8 km.) east-northeast of Knoxville; (107) Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville; and (119) beneath Nolichucky shale on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County, all in Tennessee.

CREPICEPHALUS COOSENSIS, new species

Plate 32, figs. 3, 3*a-f*

This fine species occurs with a somewhat earlier fauna than that of *C. iowensis* and other species referred to *Crepicephalus* with the exception of *C. liliana* and *C. augusta* (pl. 29). It belongs with the *C. iowensis* group of species and differs from them by its broad frontal limb and border and strongly marked pygidium. The thorax has 12 segments and the axial lobe of the pygidium five rings and a terminal section.

The large dorsal shield has a length of 6.5 cm. exclusive of the spine of the pygidium. Fragments of the cranidium indicate that a few individuals attained a length of about 7.5 cm.

Outer surface minutely granular and apparently minutely punctate. Fine irregular venation lines radiate from in front of the glabella across the frontal limb to the edge of the border.

All the known specimens of this species occur on the exterior of, or in siliceous nodules that weather out of, a dark argillaceous shale of the Conasauga formation. The associated fauna is a large one, and includes: *Laotira cambria* Walcott, *Brooksella alternata* Walcott, *Micromitra alabamaensis* (Walcott), *Lingulella hayesi* (Walcott), *Acrothele bellula* Walcott, *Acrotreta kutorgai* Walcott, *Ptychoparia,* several species, *Anomocare,* several species, and *Olenoides curticei* Walcott.

Formation and locality.—Middle Cambrian: (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in a dark argillaceous shale of the lower part of the Conasauga formation; east of Center, near Blaine, Coosa Valley, Cherokee County, Alabama.

CREPICEPHALUS CORIA, new species

Plate 33, figs. 3, 3*a-g*

Crepicephalus texanus Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, p. 178. (Name listed in fauna 1*b* and 1*c* of section.)

This species is much like *C. texanus* (pl. 30). It differs in having 14 instead of 12 thoracic segments and a uniformly sized and distributed granulation on the exterior surface of the test. Test probably punctate, as minute pits occur between the surface granules.

The largest cranidium has a length of 3.5 cm.

The variation in the width of the frontal border is similar to that of *C. texanus,* and the glabella is very much alike in the two forms. *Crepicephalus coria* is the representative in western Utah of *C. texanus.*

Formation and locality.—Upper Cambrian: (30n, 30 o, 14v) Weeks formation, in 1*b* and 1*c* of section (Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, p. 175); (30h, 30i) Orr formation; near base and about 275 feet from 2*a* of section (*Idem*, p. 177); north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

CREPICEPHALUS DIS, new species

Plate 32, figs. 1, 1*a-c*

Crepicephalus WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, pp. 175, 176. (Name listed in geological section.)

This is the *C. iowensis* (pl. 29) representative in the Cordilleran province. It has the same form of glabella except that it is a little more conical or rounded in front; the frontal limb is narrower, and the occipital ring is narrower towards the ends when viewed from above. The associated pygidia differ in outline of the postero-lateral portions of the border, which in *C. dis* are prolonged into short spines and in *C. iowensis* into long, sharp spines.

Crepicephalus dis is associated with *C. coria*, but neither the cranidium nor the pygidium is similar to that species. The pygidium is much like that of *C. camiro* (pl. 32, fig. 2*a*) except that the axial lobe is shorter and has three instead of five or six rings.

Surface of test smooth to the unaided eye, and minutely pitted and apparently punctate as seen by a strong lens.

Formation and locality.—Upper Cambrian: (30n, 30 o, 14v) Weeks formation, in 1*b* and 1*c* of section (Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, p. 175); (30j) Orr formation; 1*e* of section (*Idem*, p. 177); north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

CREPICEPHALUS IOWENSIS (Owen)

Plate 29, figs. 1, 2, 2*a-f*

Dikelocephalus ? iowensis OWEN, 1852, Rept. Geol. Surv. Wis., Iowa, Minn., p. 575, pl. 1, fig. 4; pl. 1A, fig. 13. (Describes and illustrates species.)

Conocephalites iowensis (Owen) HALL, 1863, Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., p. 162, pl. 7, figs. 29-33; pl. 8, figs. 10-12, 30. (Describes and illustrates species.)

Conocephalites iowensis (Owen) SHUMARD, 1863, Trans. Acad. Sci. St. Louis, Vol. 2, p. 102. (Refers to species and having found the head.)

Conocephalites iowensis (Owen) HALL, 1867, Trans. Albany Inst., Vol. 5, p. 149, pl. 7, figs. 29-33; pl. 3, figs. 10-12, 30. (Reprint of paper of 1863.)

Ptychoparia (*Crepicephalus*) *iowensis* (Owen) WALCOTT, 1884, Bull. U. S. Geol. Surv., No. 10, p. 36, pl. 6, figs. 2, 2*a*. (Refers to use of *Crepicephalus* as a subgenus and illustrates a cranidium and pygidium.)

Ptychoparia (*Crepicephalus*) *iowensis* (Owen) LESLEY, 1889, Geol. Surv. Pa., Rept. P 4, p. 832. (2 text figs. only.)

Crepicephalus iowensis (Owen) WALCOTT, 1899, Monogr. U. S. Geol. Surv., Vol. 32, Pt. 2, p. 459. (Refers to this species as type of genus *Crepicephalus*.)

To the description given by Hall [1863] we may now add that the thorax has 12 segments; and we are also enabled to illustrate the form and general character of the entire dorsal shield, which is rather closely related to that of *C. texanus* (pl. 30). There is considerable variation in the form of the pygidium. In Owen's illustration [1852, pl. IA, figs. 11, 13, 15] the postero-lateral spines diverge from the median line of the axial lobe, but this divergence decreases in other specimens until the sides of the pygidium are nearly straight, and the ends of the spines curve inward toward the median line. The degree of the divergence varies in specimens from different localities, but in the collection from Menomonie there is variation from those that are strongly divergent to those that are diverging but slightly from the median line.

The reasons for considering this species the type of the genus are given under the description of the genus (p. 199).

Crepicephalus iowensis is very abundant in the shaly and thin-bedded sandstone of Wisconsin and eastern Minnesota. Only rarely have the cephalon, thorax, and pygidium been found unbroken; there is only one example known to me in which they are united in their natural position, and this is broken so that less than one-half of the dorsal shield remains; this specimen is used as the base for the restored figure 1 on plate 29.

In all specimens known to me the test has disappeared, but from the casts in fine sandstone the outer surface appears to have been smooth.

The larger cranidium has a length of 30 mm., and the one specimen showing the length of the dorsal shield has the following dimensions:

Total length	78 mm.
Cephalon	12.5 mm.
Thorax	29.5 mm.
Pygidium	14 mm.

Crepicephalus iowensis is very abundant in the Eau Claire formation and the upper part of the Dresbach formation.

Formation and locality.—Upper Cambrian: Eau Claire formation; (84) Dresbach, opposite the mouth of Black River, Winona County, Minnesota.

Also (78a) topmost bed on Mount Washington, near Eau Claire; (98, 98x) upper beds, middle beds, and lower beds near Eau Claire, Eau Claire County; (79x) near the flour mill on Beaver Creek, north of Galesville, and (100a) at Ettrick, both in Trempealeau County; (83a) Rock Falls, and (100) near Menomonie, both in Dunn County; also Dresbach formation; (83^4) lower beds just above the river, Trempealeau, Trempealeau County, all in Wisconsin.

CREPICEPHALUS LILIANA Walcott

Plate 29, figs. 5, *5a-c*

Crepicephalus liliana WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 207, pl. 28, figs. 3, *3a-c*. (Description and illustration of cranidium and pygidium.)

Crepicephalus liliana WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Survey, p. 653, pl. 96, figs. 7, *7a-c*. (Republishes illustrations of 1886.)

A detailed description of the specimen representing this species was published in 1886, and nothing has been added to it since. The illustrations are given in this paper in order that the American species referred to *Crepicephalus* may be brought together for comparative study.

Formation and locality.—Lower Cambrian: (31a) Limestones of Pioche formation, just above the quartzite on east side of anticline, near Pioche; (30) limestone 8 miles (12.8 km.) north of Bennetts Spring, on the west slope of the Highland Range, both in Lincoln County, Nevada.

CREPICEPHALUS TEXANUS (Shumard)

Plate 29, fig. 7; plate 30, figs. 1-4, *4a*

Arionellus (*Bathyurus*) *texanus* SHUMARD, 1861, Am. Jour. Sci. and Arts, 2d ser., Vol. 32, p. 218. (Description of species.)

Crepicephalus texanus Shumard sp. WALCOTT, 1899, Monogr. U. S. Geol. Survey, p. 460, pl. 65, fig. 5.

Not *Crepicephalus texanus* WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, pp. 177, 178.

Crepicephalus texanus (Shumard) GRABAU and SHIMER, 1910, North Am. Index Fos., Vol. 2, p. 283, fig. 1586. (Reproduces Walcott's figure of 1899.)

The type specimen of this species is no longer accessible, having been destroyed by fire many years ago. Its locality was given as Clear Creek, Burnet County, Texas. The geological map of the

Burnet quadrangle, U. S. Geological Survey, shows that the head waters of Clear Creek drain an area on its western side where the Cap Mountain formation occurs, and it is from this area that the type specimen undoubtedly came. In the collections made by Dr. Cooper Curtice for the United States Geological Survey there are specimens of a similar form collected in the Clear Creek drainage area from Potatotop Hill, the upper portion of which is formed of the Cap Mountain formation; there are also specimens of the cranidium from a locality in the Cap Mountain formation 10 miles northwest of Potatotop that are identical with those from Potatotop.

Dr. Shumard's description of the cranidium and pygidium from Clear Creek corresponds so closely to the specimens from Potatotop that I do not hesitate to adopt the latter as the representative of the species, although Shumard described the flattened frontal border variety of the species, and the specimens from Potatotop have the rounded and intermediate or semi-flattened border; other specimens from 10 miles northwest, near the Colorado River, show the narrow rounded, intermediate and broad frontal border.

The cranidium has a low, broadly conical glabella marked by three pairs of short lateral furrows; fixed cheeks narrow, moderately elevated; frontal limb slightly convex, arching downward to a strong, rounded transverse furrow (parallel to the front margin) that has three elongate oval transverse pits, one of which is directly in front of the glabella and one on each side in line with the posterior lateral angle of the glabella; frontal border gently convex, nearly horizontal, and varying in width so as to be a little wider or narrower than the frontal limb; it varies in width, and may be convex or almost flat.

The palpebral lobes are not preserved, but Dr. Shumard in his description stated that "a line drawn transversely across the middle of the glabella, if extended, would pass nearly through to the center of the eyes." This corresponds to the specimens from both Texas and Alabama.

The associated pygidium is described as follows: "Pygidium short and somewhat massive, sub-elliptical, axis approaching semi-cylindrical, elevated above the lateral lobes, as wide as one lateral lobe, and occupying about two-thirds the length of the pygidium; rings four, separated by deep furrows; posterior margin gently arched in the middle and armed on either side with a long, curved, diverging spine (about eight lines long); lateral lobes gently convex, segments indistinct."[1]

[1] American Jour. Sci., 2d ser., Vol. 32, 1861, p. 219.

The pygidia from Potatotop and Bartlett Hollow correspond to the above description very closely, and also to the pygidia of the *Crepicephalus* that I have identified as *C. texanus* from the Upper Cambrian of Montana.

By comparing the specimens that are of similar size from the Cap Mountain limestone of Texas and the Conasauga shales of Coosa River, Alabama, they appear to be identical. In both, the glabella is broadly conical with frontal limb of medium width and separated from the frontal rim by a strong rounded furrow marked by three slightly transverse pits. In both, the outer surface of the glabella is nearly smooth or marked by low, scattered tubercles, while the fixed cheeks, frontal limb and rim are marked by rather strong granulations or tubercles. There is also a slight node near the center of the well-defined occipital ring; at each locality we find the long and shorter glabella, narrow rounded, intermediate and wide flattened frontal rim. As the cranidia increase in size, the frontal rim broadens so as to be proportionately wider than the frontal limb.

The following is a description based upon the Alabama specimens: General form of dorsal shield broadly oval; axial lobe convex, about half as wide as the pleural lobe. Cephalon broad, transversely semicircular, with a well-defined border that varies in width from narrow in young subjects to quite broad in the older individuals. Cranidium with strong, broadly conical glabella that is marked by three pairs of short lateral furrows; occipital ring of medium width and marked at its center by a small sharp-pointed node; occipital furrow broad, rounded, and narrowing at each end; dorsal furrow about the glabella deeply impressed. Fixed cheeks relatively narrow and generally convex; palpebral lobes rather large and nearly equal to one-third the length of the cranidium on the line of the facial suture; the narrow fixed cheeks merge into the relatively strong frontal limb, which is slightly convex and sloping downward to a well-defined transverse furrow, which is marked by three more or less strong, slightly transverse pits, the center one of which is on the line of the axis of the glabella and the lateral ones are on a line with the sides of the glabella near its posterior margin; frontal border varying from a narrow, slightly convex border in young specimens to a broad flattened border in the older and larger individuals; postero-lateral limbs long, rather narrow, and marked by a well-defined intramarginal furrow. The free cheeks terminate at the genal angles in rather strong, backward-extending spines.

Thorax with 12 segments, axial lobes convex, relatively narrow; pleural lobes broad, flattened for about one-half their width from the axis, then arching gently downward and backward to their pointed ends; pleural furrows nearly as wide as the segment for about one-third of its length, where they narrow and disappear some distance within the falcate termination of the segment.

Pygidium small, strong, convex; axial lobe broad, convex, and about three-fourths the length of the pygidium; it is divided by narrow, deep transverse furrows into three segments and a terminal section; pleural lobes rising abruptly from the margin and curving gently to the dorsal furrow about the axial lobe; pleural furrows shallow and curving backward towards the base of the lateral spine that originates on each side opposite the posterior half of the axial lobe and within the outer margin; these spines have a strong base that merges into the side of the pleural lobes in such a manner as to give the impression that they were formed by the continuation outward and backward of three of the anchylosed segments of the pygidium. The strength and curvature of the spines vary somewhat, but as a rule they are much like those of figures 1, 1*a*, plate 30.

Surface of test finely punctate with strong scattered granulations over free and fixed cheeks, frontal limb and border, and raised portions of thoracic segments and pygidium; on the glabella a few rather large, low tubercles are scattered over the surface. Some specimens have a rather fine, even granulation over the glabella and other parts of the cephalon.

Measurements.—This is one of the largest trilobites known to me from the Cambrian above the "*Olenellus*" zone and below the *Dikelocephalus* zone with the exception of *Paradoxides* of the Atlantic Coast province. Fragments of the cephalon and thorax indicate a length of 21 cm. exclusive of the long spines of the pygidium. The proportions of an entire dorsal shield are shown by figure 1, plate 30.

Observations.—I have hesitated to identify the Alabama form with that from Texas, owing to the large size the latter attains, but with specimens of the cranidium of the same size the similarity is so great that there does not appear to be sufficient reason to distinguish them as distinct species. The greater proportional broadening of the frontal border of the cranidium with increase in size of the cephalon gives an appearance to the large cephala that is of specific importance unless the broadening with growth is considered. There is also widening of the base of the glabella in the Texas forms that is seldom seen in those from Alabama, but this is not persistent; the more

elongate glabella of the Alabama specimens is similar to that of the variety *elongatus* of Wisconsin.

The identification of the species at the two localities is strengthened by the occurrence in both areas of similar variations in the form of the glabella, frontal limb, furrow, and border of the cranidium.

The stratigraphic position of the Texas and Alabama specimens is the same to the extent that both occur in the lower part of the Upper Cambrian.

In the Cordilleran region an apparently identical cranidium and pygidium occur in the Upper Cambrian (358c) Abrigo limestone of the Bisbee mining district, Cochise County, Arizona. The cranidia are typical forms with intermediate and broad frontal border. An apparently identical cranidium and pygidium occur in the (151g) Gallatin limestone of northern Wyoming (fig. 4, pl. 30). The cranidium has the wide glabella, variable frontal border, and coarsely granular surface of *C. texanus* (compare fig. 4 with figs. 2 and *2b*, pl. 30). A somewhat similar form with a wide flattened frontal border occurs in the Gallatin limestone of Meagher County, Montana, that is identified with the variety *elongatus* of the Eau Claire formation of Wisconsin (pl. 29, fig. 4).

The critical study of this species with new material results in removing the form described by Whitfield as *Arionellus tripunctatus* from *C. texanus,* to which I referred it in 1899,[1] and referring it to *Crepicephalus* as a distinct species characterized by an occipital spine and narrower glabella.

Formation and locality.—Upper Cambrian: (67a) Cap Mountain formation (upper beds); limestone on Potatotop Hill, 6 miles (9.6 km.) northwest of Burnet; also (14d) Bartlett Hollow, 2 miles (3.2 km.) southeast of mouth of Fall Creek, 17 miles (27.2 km.) northwest of Burnet, both in Burnet County, Texas.

Upper Cambrian: (358c) Abrigo limestone; north side Moore Canyon, west edge Bisbee quadrangle, Bisbee district, Arizona.

Upper Cambrian: (151b) Gallatin limestone; below saddle on ridge between Pebble Creek and Soda Butte Creek, Yellowstone National Park, Wyoming.

Upper Cambrian: (151i) Gallatin limestone; 6 miles (9.6 km.) northeast of White Sulphur Springs, Meagher County, Montana.

Upper Cambrian: (90a and 91) Conasauga formation; Cedar Bluff on Coosa River, Cherokee County, Alabama. Entire speci-

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[1] Monogr. No. 32, U. S. Geol. Survey, p. 460.

mens occur in both argillaceous shale and shaly dark bluish-grey limestone.

Upper Cambrian: (16a, 89) Conasauga formation; shaly limestone interbedded in argillaceous shales, Murphrees Valley, Blount County; and (139a) near Chepultepec, Jefferson County, both in Alabama.

CREPICEPHALUS TEXANUS DANACE, new variety

Plate 29, figs. 3, 3*a*

This variety is represented by a single cranidium. It differs from *C. texanus* by having the glabella less convex, a trifle more elongate proportionally, and more transverse at the anterior end; and the frontal border is more rounded. Surface granulated as in *C. texanus*.

Formation and locality.—Upper Cambrian: (79d) Eau Claire formation; upper beds of sandstone on Mount Washington, near Eau Claire, Eau Claire County, Wisconsin.

CREPICEPHALUS TEXANUS ELONGATUS, new variety

Plate 29, figs. 4, 4*a*

Of this species the cranidium only is known. It is characterized by a proportionally longer glabella and narrower fixed cheeks, with a broad flattened frontal border. The transverse frontal furrow is also less deeply impressed than in typical specimens of *C. texanus*.

The surface of the test in both the Wisconsin and Montana specimens has coarse tubercles scattered irregularly on the glabella, fixed cheeks, and frontal limb.

Formation and locality.—Upper Cambrian: (79e) Eau Claire formation; 1 mile (1.6 km.) north of Eleva, Trempealeau County, Wisconsin.

Upper Cambrian: (151i) Gallatin limestone; north side of Smith River; 1.5 miles (2.4 km.) below mouth of Fourmile Creek, and 6 miles (9.6 km.) northeast of White Sulphur Springs, Meagher County, Montana.

CREPICEPHALUS THOOSA, new species

Plate 31, figs. 1, 1*a-k*

This species is based on cranidia and associated free cheeks and pygidia. It is of the *C. texanus* type, and differs from it in its more elongate, conical glabella, short frontal limb, and more thickly-set surface granules that occur on the cranidium, free cheeks, thoracic

segments, and pygidium. The associated pygidium is much like that of *C. tripunctatus magnispinus.*

With the exception of the great occipital spine, *C. thoosa* is closely related to *C. tripunctatus magnispinus.* The pygidium referred to the latter is proportionally narrower, but the postero-lateral spines are similar.

This species occurs in the upper part of the Conasauga shales in northeastern Alabama, the Maryville limestone of eastern Tennessee, and the Honaker limestone of western Virginia.

Formation and locality.—Upper Cambrian: (**125a**) Maryville limestone; north side of Big Creek below Harlans mill, 4 miles (6.4 km.) northeast of Rogersville; (**125**) about 50 feet below **125a**; (**123b**) upper beds of Maryville limestone, 0.5 mile (0.8 km.) east of Rogersville railway depot on left of railway, in wagon road, Hawkins County; (**107**) Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville; (**126a**) east side of Gap Creek section, 10 miles (16 km.) east of Knoxville, Knox County; (**119**) beneath Nolichucky shale on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County; (**120**) north of Bays Mountain on Beaver Creek, Sevier County, 18 miles (28.8 km.) east-northeast of Knoxville; (**118a**) Bird Bridge road, 1.5 miles (2.4 km.) south, and (**117c**) 5 miles (8 km.) southeast of Greeneville, Greene County, all above in Maryville limestone of Tennessee.

Also (**119a**) Honaker (= Maryville) limestone, 3 miles (4.8 km.) east of Greendale, Washington County, Virginia.

Also (**145a**) Conasauga shale; upper part of shale beneath Knox dolomite; 1 mile (1.6 km.) east of Gaylesville; also (**91**) Cedar Bluff, both in Cherokee County; and (**358e**) Conasauga shale, opposite car barn, city of Birmingham, Jefferson County, all in Alabama.

And (**358f**) Conasauga formation; limestone in shales, west of Red Clay, Whitfield County, Georgia.

CREPICEPHALUS TRIPUNCTATUS (Whitfield)

Plate 33, figs. 1, 1*a-b*

Arionellus tripunctatus WHITFIELD, 1876, Rept. Reconnaissance from Carroll, Montana Terr., on the Upper Missouri, to the Yellowstone National Park (Ludlow), p. 141, pl. 1, figs. 3-5. (Original description and illustrations.)

Not *Crepicephalus texanus* (Shumard) WALCOTT, 1899, Monogr. No. 32, U. S. Geol. Survey, p. 460. (Refers *Arionellus tripunctatus* Whitfield to *C. texanus* (Shumard).)

The type of this species is a cranidium with the occipital spine broken off. Whitfield also had two associated free cheeks for study. In 1898 I collected from about the same horizon in the Gallatin limestone a number of fine cranidia, also fragments of an associated pygidium. This material shows a strong resemblance between the cranidia of *C. tripunctatus* and *C. texanus,* the difference being in the thickened occipital ring and occipital spine of *C. tripunctatus.* The outer surface of the latter species is also more thickly covered with smaller granulations. The test appears to be finely punctate.

The variation in the width of the frontal border of the two species is similar, the smaller species having a proportionally narrower border than the large ones.

The closely related *C. tripunctatus magnispinus* differs from this species in having slightly narrower fixed cheeks and a much stronger and larger occipital spine.

Formation and locality.—Upper Cambrian: (358d) Gallatin limestone; Moss Agate Springs near Camp Baker, which is 18 miles (28.8 km.) northwest of White Sulphur Springs, Meagher County; also (4r) Gallatin limestone on ridge between Luce and Deep Creeks, 8 miles (12.8 km.) east of Yellowstone River and 3 miles (4.8 km.) north-northeast of Mount Delano, Park County, both in Montana.

CREPICEPHALUS TRIPUNCTATUS MAGNISPINUS, new variety

Plate 33, figs. 2, *2a-c*

This fine species is abundant at one locality in eastern Tennessee. It is the representative in the Appalachian area of *C. tripunctatus* of the Cordilleran area, and differs from that species in its narrower fixed cheeks and longer and stronger occipital spine. Both forms have the outer surface of the cranidium and free cheeks rather thickly dotted with irregularly arranged granules or small tubercles; the test appears to be finely punctate.

The associated pygidia are narrow with a long, strong, nearly straight spine projecting from the postero-lateral side of each pleural lobe. The axial lobe is broad and divided into three rings and a terminal section by strong backward-curving furrows.

Formation and locality.—Upper Cambrian: (107) Maryville limestone; Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, Knox County, Tennessee.

CREPICEPHALUS TUMIDUS, new species

Plate 31, fig. 2

This species is represented by cranidia. It differs from the cranidia of the most nearly related species, *C. texanus* and *C. thoosa*, by greater convexity of glabella and more strongly tuberculated surface. Test apparently punctate. The largest cranidium has a length of 25 mm.

It is unfortunate that we have only the cranidia of this fine species, but as they are closely allied to the cranidia of *C. texanus*, it is highly probable that the entire dorsal shield of the two forms was essentially similar.

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, on Beaver Creek, Sevier County, 18 miles (28.8 km.) east-northeast of Knoxville, Tennessee.

CREPICEPHALUS UNCA, new species

Plate 35, figs. 1, *1a-e*

The pygidium of this species is not unlike that of *C. dis* (pl. 32, fig. 1) from the House Range of Utah. It differs in having the two posterior spines of the pygidium near together and in their broader base where joining the flattened border.

The associated cranidium is similar in outline to that of *C. dis*, but differs in having proportionally broader fixed cheeks.

The largest pygidium has a length of 12 mm. exclusive of the spines.

Formation and locality.—Upper Cambrian: (79e) Eau Claire formation; Willow River Falls, near Hudson; (79) Hudson, St. Croix County, Wisconsin.

CREPICEPHALUS UNZIA, new species

Plate 34, figs. 7, *7a*

This species, like *C. unca*, is related to *C. dis* (pl. 32, fig. *1b*) and *C. augusta* (pl. 29, fig. *6b*) by the form of the pygidium, but the backward-extending spines are not attachments to the border, as the furrows indicating the anchylosed segments extend back onto the base of the spines as shown by figure *7a*. The cranidium is quite unlike that of *C. dis*. It has a concave frontal rim and border that give it a very distinct appearance.

Surface slightly pitted and test apparently punctate. The largest cranidium has a length of 7.5 mm.

Formation and locality.—Upper Cambrian: (150b) Gallatin limestone; thin-bedded limestone in divide at White Creek and Indian Creek Pass, above Red Bluffs or Chinese Wall, Lewis and Clark National Forest, Montana.

CREPICEPHALUS UPIS, new species

Plate 33, figs. 4, 4*a-d*

The cranidium and pygidium of *C. upis* recall those of *C. liliana* (pl. 29, figs. 5, 5*a*), and the outer surface is granulated in both species, but not in the same manner. The surface of *C. liliana* has rather large pustules scattered over it, while those of *C. upis* are more numerous and smaller. The pygidium is not unlike that of *C. coosensis* (pl. 32, figs. 3*b*, 3*e*). The surface of the test between the granulations is slightly pitted and the test is apparently punctate.

The largest cranidium in the collection has a length of 14 mm.

Formation and locality.—Upper Cambrian: (150b) Gallatin limestone; thin-bedded limestone in divide at White Creek and Indian Creek Pass, above Red Bluffs or Chinese Wall, Lewis and Clark National Forest, Montana.

CREPICEPHALUS, species undetermined (1)

Plate 32, figs. 4, 4*a*

An undescribed species of *Crepicephalus* of the *C. iowensis* group is represented by a form of pygidium that is closely allied to that of *C. iowensis*. It differs in having the postero-lateral spines extending diagonally outward instead of directly backward, and in being proportionally wider.

A specimen from the shaly limestone of the Conasauga formation has a length of 16 mm. and a width of 3 cm. at the anterior margin. A smaller specimen is illustrated (pl. 32, fig. 4).

Formation and locality.—Upper Cambrian: (107) Maryville limestone; Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, Knox County; (119) beneath Nolichucky shale on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County, both in Tennessee.

Also from (91) Conasauga formation; Cedar Bluff on Coosa River, Cherokee County; and (16) limestones in Conasauga (Coosa) shales, Murphrees Valley, Blount County, both in Alabama.

CREPICEPHALUS, species undetermined (2)

A second unidentified species of *Crepicephalus* is indicated by pygidia of the *C. iowensis* type from the Upper Cambrian. These

pygidia differ from those referred to *C. camiro* (pl. 32, fig. 2*a*), being more transverse in outline and having three rings in the axial lobe.

Formation and locality.—Upper Cambrian: (124a) Nolichucky shale; on Big Creek, 4 miles (6.4 km.) northeast of Rogers, Hawkins County, Tennessee; also (124b) Nolichucky shale; near Goodwins Ferry, Giles County, Virginia.

AMPHION ? MATUTINA Hall

Plate 26, fig. 8

Amphion ? matutina Hall, 1863, Sixteenth Ann. Rept. State Cab. Nat. Hist., p. 222, pl. 5A, fig. 6. (Original description and illustration.)

Amphion ? matutina Hall, 1867, Trans. Albany Inst., Vol. 5, p. 194. (A reprint of the paper of 1863.)

This species is illustrated, as the specimen in the collection shows that there was an occipital spine, also small palpebral lobes opposite the center of the glabella. The species appears to belong to an undetermined genus, but at present I do not wish to base a new genus on the broken cranidium.

Formation and locality.—Upper Cambrian: (84) Eau Claire formation; Dresbach, Winona County, Minnesota.

The specimen described by James Hall came from the lower beds near Trempealeau, Wisconsin, which also contains *Crepicephalus iowensis*, a form found with *A. ? matutina* at Dresbach.

Genus WANNERIA Walcott

Wanneria Walcott, 1910, Smithsonian Misc. Coll., Vol. 53, pp. 296-298.

WANNERIA WALCOTTANA (Wanner)

Plate 38, figs. 1, 2

Olenellus (Holmia) walcottanus Wanner, 1901, Proc. Washington Acad. Sci., Vol. 3, pp. 267-269, pl. 31, figs. 1, 2; pl. 32, figs. 1-4. (Described and discussed as a new species.)

Wanneria walcottanus Walcott, 1910, Smithsonian Misc. Coll., Vol. 53, pp. 302-304, pl. 30, figs. 1-12; pl. 31, figs. 12, 13. (Changes generic reference. Comments upon and illustrates species.)

Through the courtesy of Mr. Noah Getz and Dr. H. Justin Roddy I had the opportunity of photographing a cephalon of this species that has an unusually well-preserved surface. The cephalon has a length of 9.5 cm. and a width at base of 15.5 cm. The reticulated surface is essentially of the same character as that on a thoracic segment and hypostoma of this species from near York, Pennsyl-

vania.[1] It is also of the same type as the surface of *Olenellus reticulatus* Peach[2] from Scotland.

Formation and locality.—Lower Cambrian: (12x) Argillaceous shaly beds 1 mile (1.6 km.) north of Rohrerstown, Lancaster County, Pennsylvania.

Family ORYCTOCEPHALIDÆ Beecher

VANUXEMELLA, new genus

Dorsal shield small, subelliptical, moderately convex, and with strongly marked axial lobe. Cephalon semicircular in outline; glabella large, slightly expanding in front and slightly narrowed opposite the palpebral lobes; it terminates anteriorly on the frontal margin, and posteriorly is separated from the narrow occipital segment by a strong transverse furrow; two pairs of faint pits indicate the position of glabella furrows; fixed cheeks about one-half the width of glabella and with a narrow palpebral lobe about one-fourth to one-third the length of the cephalon and placed at about the transverse center of the cephalon. The facial sutures cut the posterior margin of the cephalon on a line with the outer margin of the palpebral lobes and bend inward slightly to the base of the palpebral lobes, about which they curve, and then curve slightly inward toward the margin near the glabella. Free cheeks of medium width with posterior margin bent forward at the intergenal angle to meet the base of the genal spine. The palpebral ridges cross the fixed cheeks to the dorsal furrows beside the glabella.

Thorax with four or five segments; pleuræ with strong longitudinal furrow and short, falcate ends.

Pygidium with strong axial lobe terminating just within the margin and crossed by five or six furrows which continue laterally on the pleural lobes and outline three or four segments that have a short, falcate end beyond the line of the border of the pygidium; on each side of the center of the posterior margin, at about the ends of the central third, a small, strong spine extends directly backward, and two very short spines occur between them, one on each side of the center of the posterior margin of the pygidium.

Surface slightly roughened and apparently minutely punctate.

Genotype.—*Vanuxemella contracta* Walcott. Second species, *Vanuxemella nortia*, new species.

Stratigraphic range.—Upper beds of Lower Cambrian.

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[1] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 31, figs. 12 and 13.

[2] *Idem*, pl. 39, figs. 10, 11.

Geographic distribution.—*Vanuxemella contracta* occurs (localities 4v, 5j) in the Lewis and Clark Forest Reserve of northern Montana, and *Vanuxemella nortia* at about the same stratigraphic horizon, judging from the associated fauna, on the south slope of Mount Bosworth (locality 35c), British Columbia, Canada.

Observations.—This genus is represented by two species from the upper part of the Lower Cambrian. It is a simple form that has some features suggesting *Albertella*.[1] It differs in absence of glabellar furrows, shorter eye lobes, absence of prolonged third segment of thorax, and in having four instead of seven thoracic segments. The long spines of the pygidium spring from about the fifth segment, while in *Albertella* they appear to be the extension of the first or second anterior segment.

Vanuxemella also has an interesting feature in the union in the pygidium of three otherwise true thoracic segments. If these three anterior segments were free, the resemblance to *Albertella* would be much stronger. The genus may be characterized as an undeveloped form of the latter genus.

The cephalon of *Karlia stephenensis* Walcott[2] has an expanding glabella, but it also has quite a different glabella and fixed cheeks, and it has seven segments and a minute pygidium.

The generic name is given in memory of Lardner Vanuxem, the geologist who surveyed the "Third District of the State of New York."

VANUXEMELLA CONTRACTA, new species

Plate 36, figs. 4, 4*a*

The description and observations under the genus and the illustrations give all that is known of the species. There are five entire specimens and a few cranidia.

Dimensions.—A dorsal shield 12 mm. in length has the following dimensions:

Cephalon.	mm.
Length	6
Width at posterior margin	9
Width of base of glabella	8

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pls. 1 and 2.

[2] Proc. U. S. Nat. Mus., 1888, Vol. 11, 1889, p. 445. See plate 36, fig. 8, of this paper.

Thorax.	
Length	3.5
Width of first segment	8
Width of axial lobe	3
Pygidium.	
Length	5
Width of axial lobe	2.5

Observations.—The associated fauna at localities **4v** and **5j** includes:

Micromitra (*Iphidella*) *pannula* (White).
Obolus (*Westonia*) *ella* (Hall and Whitfield).
Acrothele colleni Walcott.
Acrothele panderi Walcott.
Wimanella simplex Walcott.
Ptychoparia sp.
Olenopsis americanus Walcott.
Albertella helena Walcott.
Bathyuriscus ? sp.
Vanuxemella contracta Walcott.

This fauna is of the same type as that found with *Vanuxemella nortia* in Canada (see p. 223).

Formation and locality.—Lower Cambrian: (**4v**) About 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, in a shale which corresponds in stratigraphic position to shale No. 6 of the Dearborn River section, Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.); and (**5j**) above the quartzitic sandstones, in a shale corresponding to the same position, about 6 miles (9.6 km.) west-northwest of Scapegoat Mountain, on the Continental Divide between Bar Creek and the headwaters of the south fork of North Fork of Sun River, Coopers Lake quadrangle (U. S. G. S.), both in Powell County, Montana.

VANUXEMELLA NORTIA, new species

Plate 36, fig. 5

This species differs from *Vanuxemella contracta* in having a greater expansion of the glabella towards the frontal margin; longer palpebral lobes; five instead of four thoracic segments, and smaller posterior spines on the pygidium.

The fauna associated with this species includes at locality **35c** the following:

Micromitra (Paterina) wapta Walcott.
Obolus parvus Walcott.
Acrothele colleni Walcott.
Wimanella simplex Walcott.
Hyolithellus.
Hyolithes.
Albertella bosworthi Walcott.
Albertella helena Walcott.
Bathyuriscus.
Agraulos stator Walcott.
Ptychoparia.

Formation and locality.—Lower Cambrian: (35c) Drift blocks of siliceous shale supposed to have come from the Mount Whyte formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia, Canada.

Genus KARLIA Walcott

Karlia WALCOTT, 1889, Proc. U. S. Nat. Mus., Vol. 11, p. 444. (Described as below.)

Form elongate-oval, convex. Head longitudinally semicircular, deeply marked by the dorsal furrows. Glabella clavate, broadly expanded in front, with or without faint glabellar furrows. Occipital furrow well defined. Fixed cheeks subtriangular; posterior furrow broad; eye lobe small; free cheeks narrow. Hypostoma with a thick, rounded anterior margin that is produced into the large lateral wings, the sides of which extend one-half way back on the oval, convex body; posterior marginal rim strong and separated from the body by a well-defined sulcus.

Thorax with seven segments; axis with a central spine on each segment; pleural lobes with a broad groove; anterior lateral ends of pleuræ faceted.

Pygidium short, transverse, four to five segments in the axis, lateral lobes slightly grooved.

Surface granulose.

Genotype.—*Karlia minor* Walcott.

Stratigraphic range.—Middle Cambrian.

Geographic distribution.—Eastern Newfoundland; Canadian Rocky Mountains, British Columbia, Canada.

Observations.—The compact, strong dorsal shield of *Karlia* at once recalls that of *Bathyuriscus.* It differs from the latter in its small eye lobes, and seven instead of 10 or 11 thoracic segments.

Two species only have thus far been referred to the genus.

KARLIA MINOR Walcott

Plate 36, figs. 7, *7a-c*

Karlia minor WALCOTT, 1889, Proc. U. S. Nat. Mus., Vol. 11, p. 445. (Described as below.)

Form elongate-oval, convex. Average size, 7 mm. in length by 3 mm. in breadth. Head longitudinally semicircular, convex; frontal rim a narrow margin which passes into a stronger rim on the sides. Glabella clavate, expanding from the base to twice the width in front, marked by four pairs of short, faint glabellar furrows; occipital furrow deep; occipital ring strong and with a sharp, slight node at the center. The broad, deep dorsal furrows unite with the posterior furrows to separate the strongly convex subtriangular fixed cheeks; eye lobe short, narrow, and defined by a well-marked groove from the cheek; the groove extends forward to the dorsal furrow. Free cheeks narrow; marginal rim round and strong; posterior angle pointed, but not known to be extended into a spine.

Thorax with seven segments; median lobe convex and with a very short node or spine at the center of each segment; pleural lobes flat to the geniculation of the pleuræ, where the outer half of the segments is bent obliquely downward and slightly backward; pleural groove the full width of the segment to the geniculation, where it abruptly tapers to a point by the cutting in of the facet on the anterior side of the segment.

Pygidium of medium size, transversely semicircular; axis convex and crossed by three or four rings and the terminal lobe; the rings are extended out on the lateral lobes as broad, low ridges trending obliquely backward to the rounded margin.

Surface of the head granulated; thorax and pygidium apparently smooth.

All the specimens seen are small, none exceeding 10 mm. in length.

Formation and locality.—Middle Cambrian: (1) Manuels formation; Manuels Brook, Conception Bay, Newfoundland.

KARLIA STEPHENENSIS Walcott

Plate 36, fig. 8

Menocephalus salteri ? ROMINGER, 1857, Proc. Acad. Nat. Sci., Philadelphia, Pt. 1, p. 16, pl. 1, fig. 6. (Described and figured.)

Karlia stephenensis WALCOTT, 1889, Proc. U. S. Nat. Mus., Vol. 11, p. 445. (Described as below.)

Karlia stephenensis WALCOTT, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 3, fig. 4. (Specimen figured.)

This species differs from the *K. minor* in its greater size, 40 mm. in length by 30 mm. in breadth; the fixed cheeks are wider and the grooves on the pleuræ are narrower. In one of the large specimens the surface of the glabella is covered with fine, irregular elevated striæ.

Formation and locality.—Middle Cambrian: (14s) Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian, on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railway, British Columbia, Canada.

HANBURIA, new genus

General outline of dorsal shield a broad oval; convex; axial and pleural lobes clearly defined.

Cephalon transverse, semicircular when not distorted; genal angles rounded on the postero-lateral limbs; marginal border narrow and wire-like on the outer margins; posterior border broader and flatter and well defined by a narrow furrow that curves forward at the genal angles to unite with the narrow furrow within the outer border. Glabella large, increasing in width by gradual divergence of the sides to the broadly rounded transverse frontal margin; three short raised lobes, one outlined on each side by furrows or depressions that join a longitudinal depressed area extending along the median line; dorsal furrow beside the glabella indistinctly defined; occipital ring narrow, transverse, and a little raised above the slight occipital furrow; frontal limb wider than the border in advance of the glabella. Fixed cheeks broad, slightly convex, and with rounded genal angles. Free cheek, if present, narrow, elongate, narrowing to a point where it joins the border posteriorly and anteriorly in front of the antero-lateral angle of the glabella. Supposed eye lobe indistinct and it may not be present; it appears to be situated opposite the anterior fourth of the glabella, but it may be only a slight flexure of the thin test.

The facial sutures are very uncertain, and it is doubtful if they are present at all.

Thorax with seven sharply defined narrow segments. Axial lobe about two-thirds the width of the palpebral lobes and clearly outlined by the dorsal furrows; pleural lobes flattened; each pleural segment terminates in a blunt rounded end; it has a broad rounded furrow that occupies nearly all its surface for about three-fifths of its length and then narrows to a point just inside the outer end of the segment; a slightly faceted surface extends along the outer anterior edge of the segment, and the back edge is rounded.

Pygidium large; axial lobe distinct and narrowing from the front margin to within a short distance of the posterior margin; it is divided into six rings and a short terminal section by narrow transverse furrows; on the broad pleural lobes seven anchylosed pleural segments similar in appearance to those of the thorax extend from the axial lobe across to the outer rim.

Surface apparently finely and minutely granular or pustulose.

Dimensions.—The largest dorsal shield has a length of 24 mm.

Genotype.—*Hanburia gloriosa* Walcott.

Stratigraphic range.—Middle Cambrian: Burgess shale member of Stephen formation.

Geographic distribution.—Limited to fossil bed on ridge between Mounts Wapta and Field, west of the Continental Divide, British Columbia, Canada.

Observations.—The existence of free cheeks and facial sutures is problematical, owing to the compression of the thin test along the edge of the cephalon. They seem to be indicated and to form a part of the margin opposite the anterior third of the glabella. There is also a slight line that may be traced diagonally backward across the inner portion of the fixed cheek from about opposite the anterior edge of the middle lobe or tubercle of the glabella. This is suggestive of the false "eye line" of *Conocoryphe*. As I expect to work the Burgess Pass fossil quarry another season, it may be that a more perfect cephalon will be found of this species. The large pygidium and few thoracic segments suggest the order Opisthoparia and family Asaphidæ rather than the order Proparia.

HANBURIA GLORIOSA, new species

Plate 36, figs. 3, 4

The generic description includes what is known of this species. Three specimens have been found during the five seasons' collecting at the fossil quarry. These are all compressed in the fine shale, and, like *Burlingia hectori*[1] from the same general horizon on Mount Stephen, had a very delicate test.

Formation and locality.—Middle Cambrian: (**35k**) Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Mount Wapta, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia, Canada.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 15, pl. 1, fig. 8.

Genus TSINANIA Walcott

Tsinania WALCOTT, 1914, Smithsonian Misc. Coll., Vol. 64, p. 43. (Genus described.)

Genotype.—*Illænurus canens* (Walcott) [Cambrian Faunas of China, Carnegie Inst. of Washington, Pub. No. 54, 1913, p. 222, pl. 23, fig. 3].

TSINANIA CLEORA Walcott

Plate 36, figs. 9, 9*a-c*

Tsinania cleora WALCOTT, 1914, Smithsonian Misc. Coll., Vol. 64, p. 43. (Name mentioned in text.)

The cranidium of *T. cleora* is much like that of *T. canens*. It differs in being longer in proportion to the width. The associated free cheek (fig. 9*a*) is large, broad, and gently convex to the outer margin. An associated thoracic segment has the pleural lobe with a very faint longitudinal furrow. The associated pygidium is transverse, about twice as wide as long, and marked by a low axial lobe that becomes very inconspicuous toward the posterior margin of the pygidum. Only a slight trace of transverse furrows can be detected on the matrix of the axial lobe. The pleural lobes are about twice as broad as the axial lobe. The test is thick and apparently smooth on its outer surface.

The largest cranidium has a length of 14 mm. An associated pygidium has the same length with a width of 28 mm.

The pygidium of *T. cleora* is proportionally shorter than that of *Tsinania canens*,[1] but the general character is the same in the two species and quite unlike the pygidium of *Illænurus quadratus*.[2]

Numerous specimens of the cranidium and pygidium are associated, and the only other trilobitic remains are those of small species of *Agraulos* and *Solenopleura*-like forms. The associated brachiopods are *Schizambon typicalis* Walcott ? and *Eoorthis desmopleura* (Meek).

This species is referred to the Upper Cambrian, but it may belong to a lower Ozarkian fauna that has not yet been well determined and probably will not be until the various faunal horizons of the lower Pogonip limestones have been studied in the field.

Formation and locality.—Upper Cambrian: (30w) Notch Peak formation; drift bowlder of limestone supposed to have come from

[1] Cambrian Faunas of China, Carnegie Inst. of Washington, Pub. No. 54, 1913, p. 222, pl. 23, fig. 3.

[2] 16th Ann. Rept. New York State Cab. Nat. Hist., 1863, pl. 7, fig. 56.

the beds forming 1*a* of the Notch Peak limestone on Notch Peak, found 2 miles (3.2 km.) south of Marjum Pass, House Range, Millard County, Utah.

TSINANIA ELONGATA, new species

Plate 36, figs. 10, 10*a*

This species is founded on a small pygidium that is longer in proportion to its width than described species. It has a length of 4 mm. and a width of 2.5 mm. in front of the small palpebral lobes. The postero-lateral limbs are relatively large and a posterior occipital ring is very faintly defined. The longitudinal outline of the cranidium is nearly flat from its posterior margin to the anterior line of the palpebral lobes, where its gentle curve increases so as to bring the anterior margin far below the level of the palpebral lobes.

This is a small species allied to *Tsinania canens*[1] from eastern China. It is associated with *Dikelocephalus ? dalyi* Walcott,[2] and is supposed to be of Upper Cambrian age. Several undescribed species that occur in Upper Cambrian formations of the Appalachian region of southeastern North America are closely related to this species.

The only associated species is *Dikelocephalus dalyi* Walcott.[3]

Formation and locality.—Upper Cambrian: (346e) Limestone nodules in calcareous shales in rock cut on Canadian Pacific Railway, 54.5 miles (87.2 km.) west of Field, and 2 miles (3.2 km.) west of Donald Station, British Columbia, Canada. (R. A. Daly, 1912.)

Type specimen in Victoria Memorial Museum, Ottawa, Canada.

CONASAUGA FORMATION

In the Coosa Valley and adjoining areas the shales and interbedded limestones referred to the Conasauga formation include both Upper and Middle Cambrian species. It is quite probable that a detailed study of the formation will result in the separation of the dark shales with the so-called " cobble " beds, and containing a Middle Cambrian fauna, from the lighter colored shales and interbedded limestones. When this is done the term Conasauga will be restricted to the Upper Cambrian, and the Middle Cambrian beds will be given a formation name.

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[1] Research in China, Carnegie Inst. of Washington, Vol. 3, Pub. No. 54, 1913, p. 222, pl. 23, fig. 3.

[2] Smithsonian Misc. Coll., Vol. 57, 1914, p. 367, pl. 64, figs. 1, 1*a*, 2, 3, 4, 4*a*, 5.

[3] Idem, p. 366.

DESCRIPTION OF PLATE 24

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Acrocephalites stenometopus (Angelin) 181

FIGS. 1, 1*a*. (× 3.) Reproduction of photograph of the type specimen of the cranidium.

1*b*. (× 3.) Matrix of free cheek assigned to the cranidium.

The specimens illustrated are from the (309n) *Agnostus lævigatus* zone of the Middle Cambrian limestone at Gudhem, Skaraborg (Vestergötland), Sweden. Type in Geol. Min. Inst., Lund, Sweden. Plastotype, U. S. National Museum, Catalogue Nos. 61555 and 61556.

Acrocephalites americanus Walcott 177

FIG. 2. (× 2.5.) Dorsal view of a nearly entire cranidium, with the outline of the missing parts restored from other specimens. U. S. National Museum, Catalogue No. 61557.

2*a*. (× 3.) A cranidium varying in details from fig. 2. U. S. National Museum, Catalogue No. 61558.

2*b*. (× 8.) Surface of the cranidium of fig. 2 on left side of fixed cheek in front of ocular ridge.

3. (× 1.5.) An imperfect dorsal shield with 29 thoracic segments. This is the only specimen known to me that indicates the appearance of the thorax. (Locality **90x**.) U. S. National Museum, Catalogue No. 61559.

3*a*. (× 4.) Cranidium and portion of thorax of a specimen from the shale in which the siliceous nodule specimens represented by figs. 2, 2*a-c*, and 3 were embedded. (Locality **112**.) U. S. National Museum, Catalogue No. 61560.

3*b*. (× 5.) Side view of a free cheek associated with this species. (Locality **16d**.) U. S. National Museum, Catalogue No. 61561.

The specimens represented by figs. 2, 2*a-b* are from the siliceous nodules of locality **89x**. These occur in the Conasauga shales of the Middle Cambrian, Coosa Valley, Livingston, Floyd County, Georgia.

Figs. 3, 3*a-b* are of specimens from the shale in which the nodules occur, (**90x**, **112**, and **16d**) Coosa Valley, Cherokee County, Alabama.

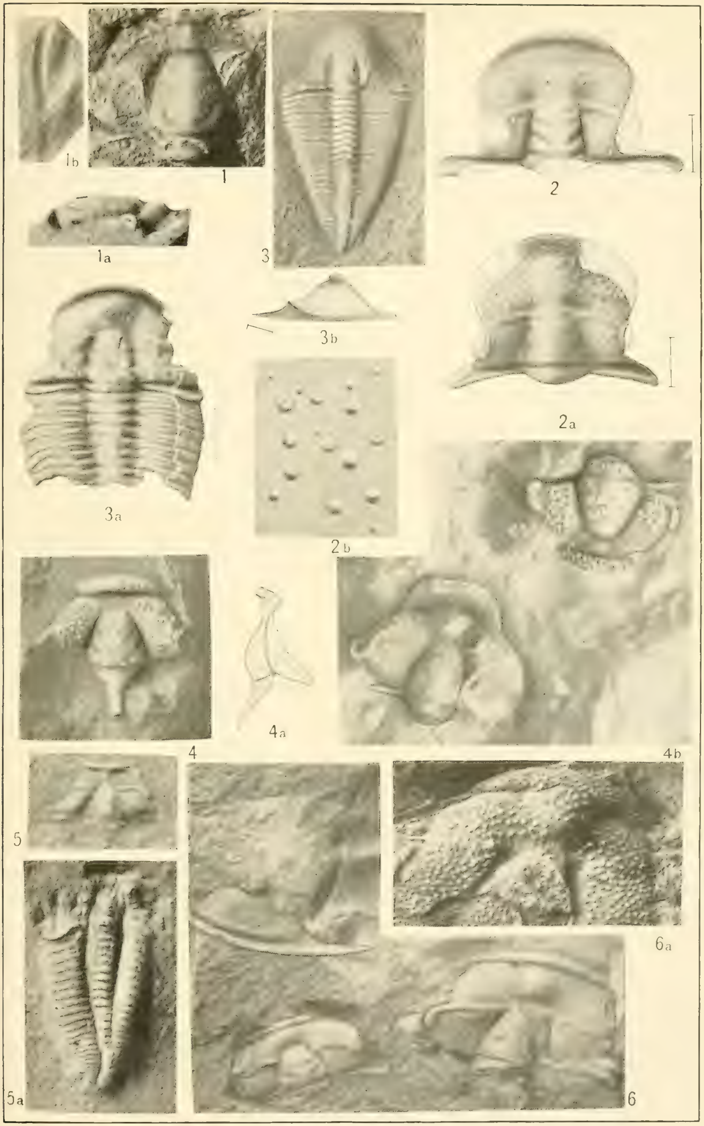
Acrocephalites haynesi Walcott 179

FIGS. 4, 4*a*. (× 3.) Dorsal view and side outline of a small cranidium on which the tubercle in front of the glabella is only slightly developed.

4*b*. (× 3.) Dorsal view of two cranidia illustrating variation in frontal tubercle.

The specimens illustrated by figs. 4, 4*a*, and 4*b* are from the Upper Cambrian, Meagher limestone on Pole Creek, Montana. The type specimen is at the Museum of Comparative Zoölogy, Cambridge, Massachusetts.

Plastotypes, U. S. National Museum, Catalogue No. 61562, 61563.



ACROCEPHALITES

PAGE

Acrocephalites multisegmentus Walcott 180

FIG. 5. (× 4.) Dorsal view of cranidium with short occipital spine broken off. U. S. National Museum, Catalogue No. 61564.

5*a*. (× 4.) Dorsal view of a nearly entire dorsal shield. U. S. National Museum, Catalogue No. 61565.

The specimens illustrated by figs. 5 and 5*a* are from localities **30n, 30 o,** the Upper Cambrian: Weeks formation; 2 miles (3.2 km.) south of Marjum Pass, Millard County, Utah.

Acrocephalites tutus Walcott.. 181

FIG. 6. (× 3.) Cranidia and free cheeks as they occur on surface of shale. U. S. National Museum, Catalogue No. 61566.

6*a*. (× 4.) Enlargement of the anterior part of a cranidium to illustrate frontal limb and rim, and granulated surface. U. S. National Museum, Catalogue No. 61567.

The specimens illustrated are from locality **141,** Middle Cambrian: the Conasauga shale near Cave Spring, Floyd County, Georgia.

DESCRIPTION OF PLATE 25

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Acrocephalites insignis Walcott.. 179

FIG. 1. (× 4.) Cranidium with strong palpebral lobes, and ridges crossing fixed cheeks. U. S. National Museum, Catalogue No. 61568.

1*a*. (× 4.) Nearly entire dorsal shield crushed in the shale. U. S. National Museum, Catalogue No. 61569.

1*b*. (× 4.) A cranidium and part of thorax. Free cheek and outline of eye preserved. U. S. National Museum, Catalogue No. 61570.

The specimens represented by figs. 1, 1*a-b* are from locality 112, Middle Cambrian: Conasauga shale; east of Center, Cherokee County, Alabama.

Alokistocare subcoronatum (Hall and Whitfield)........................ 187

FIG. 2. (× 4.) Cranidium of the type specimen of the species. U. S. National Museum, Catalogue No. 15442.

The type specimen and cotypes are from a limestone of Lower Cambrian age, (31c, 54 o) Ute Peak, Wasatch Range, Cache County, Utah.

Alokistocare althea Walcott.. 184

FIG. 3. (× 3.) Cast of cranidium in fine-grained sandstone. U. S. National Museum, Catalogue No. 61571.

3*a*. (× 2.) Matrix of a cranidium in fine-grained sandstone. U. S. National Museum, Catalogue No. 61572.

The specimens illustrated are from locality 74, Middle Cambrian: Tapeats sandstone; at head of Nunkoweap Valley, Grand Canyon of the Colorado River, Arizona.

4. (× 2.) Cephalon and portion of thorax. U. S. National Museum, Catalogue No. 61573.

4*a*. (× 2.) Entire dorsal shield with exception of free cheeks. Both 4 and 4*a* are compressed in fine arenaceous shale. U. S. National Museum, Catalogue No. 61574.

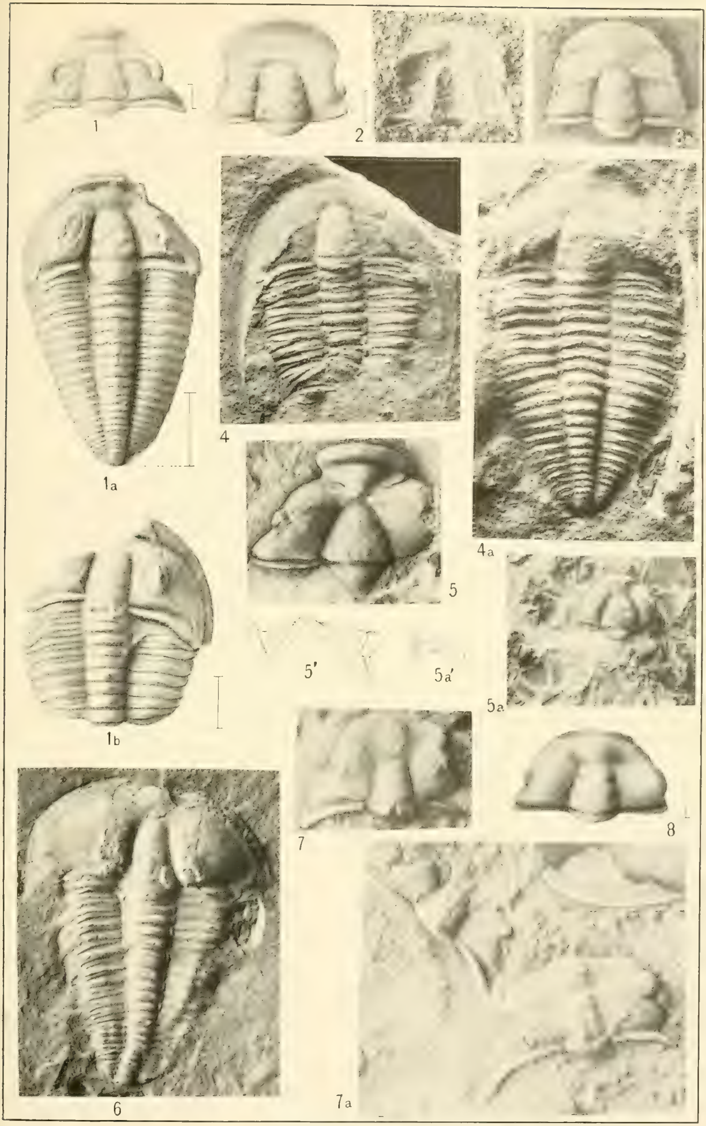
The specimens represented by figs. 4 and 4*a* are from the Upper Cambrian: (74e) Bright Angel shale; Cameron trail, Grand Canyon of the Colorado River, Arizona.

Alokistocare ? labrosum Walcott.. 184

FIGS. 5, 5′. (× 3.) Dorsal view of the cast of the interior surface of a cranidium and outline of profile. U. S. National Museum, Catalogue No. 61575.

5*a*. (× 3.) A small cranidium from which the test has been exfoliated. U. S. National Museum, Catalogue No. 61576.

The specimens illustrated by figs. 5 and 5*a* are from the Middle Cambrian: (5f) limestone in Wolsey shale, 11 miles (17.6 km.) south of Neihart, Cascade County, Montana.



CAMBRIAN TRILOBITES

PAGE

Alokistocare pomona Walcott 186

FIG. 6. (× 3.) Entire dorsal shield. The type specimen of the species compressed in fine shale. U. S. National Museum, Catalogue No. 61577.

From Middle Cambrian: (159f) Wolsey shale; Sixteen-mile Canyon, Meagher County, Montana.

Alokistocare linnarssoni (Walcott) 185

FIG. 7. (× 2.) Type specimen of species. Cranidium. U. S. National Museum, Catalogue No. 24611.

7a. (× 2.) Two cranidia showing variation in width of fixed cheek as compared with fig. 7, also free cheek. U. S. National Museum, Catalogue No. 24611.

The specimens represented by figs. 7 and *7a* are from the Middle Cambrian: (58) Shaly limestone in Secret Canyon shale; New York and Secret Canyons, Eureka district, Nevada.

Alokistocare ? prospectense (Walcott) 186

FIG. 8. (× 4.) Dorsal view of a somewhat flattened cranidium which is the type specimen of the species as it occurs in a shaly limestone. U. S. National Museum, Catalogue No. 15441.

The type specimen is from the Middle Cambrian: (52a) Prospect Mountain formation; Prospect Mountain, Eureka mining district, Nevada.

DESCRIPTION OF PLATE 26

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Acrocephalites ? majus Walcott 180

FIG. 1. (Natural size.) Large cranidium doubtfully referred to this genus. U. S. National Museum, Catalogue No. 61578.

The specimen illustrated is from the Middle Cambrian: (4g) Wolsey shale: 1 mile (1.6 km.) north of forks of East and West Gallatin Rivers, Gallatin County, Montana.

Acrocephalites ? vulcanus (Billings) 182

FIG. 2. (× 3.) Cranidium from the type locality of the species. U. S. National Museum, Catalogue No. 15437.

From Lower Cambrian: (25) Shaly sandstone just above Parkers Quarry, Georgia, Franklin County, Vermont.

This is the original of fig. 4, pl. 26, Bull. U. S. Geol. Survey, No. 30, 1886.

Acrocephalites aoris Walcott 178

FIG. 3. (× 2.) Dorsal view and side outline of cranidium. U. S. National Museum, Catalogue No. 61579.

3a. (Natural size.) The same cranidium as that represented by fig. 3.

3b. (× 1.5.) A broken cranidium showing occipital ring. U. S. National Museum, Catalogue No. 61580.

The specimens illustrated are from locality 107d, Middle Cambrian: Conococheague ? limestone; 1 mile (1.6 km.) north of Henrietta, Blair County, Pennsylvania.

Menomonia calymenoides (Whitfield) 162

FIGS. 4, 4′. (× 2.) Dorsal view and side outline of an entire cranidium. U. S. National Museum, Catalogue No. 61581.

4a, 4a′. (× 2.) Dorsal view and side outline of a broken cranidium. U. S. National Museum, Catalogue No. 61582.

4b. (Natural size.) A nearly entire specimen of the thorax, pygidium, and base of cephalon with 42 thoracic segments. U. S. National Museum, Catalogue No. 61583.

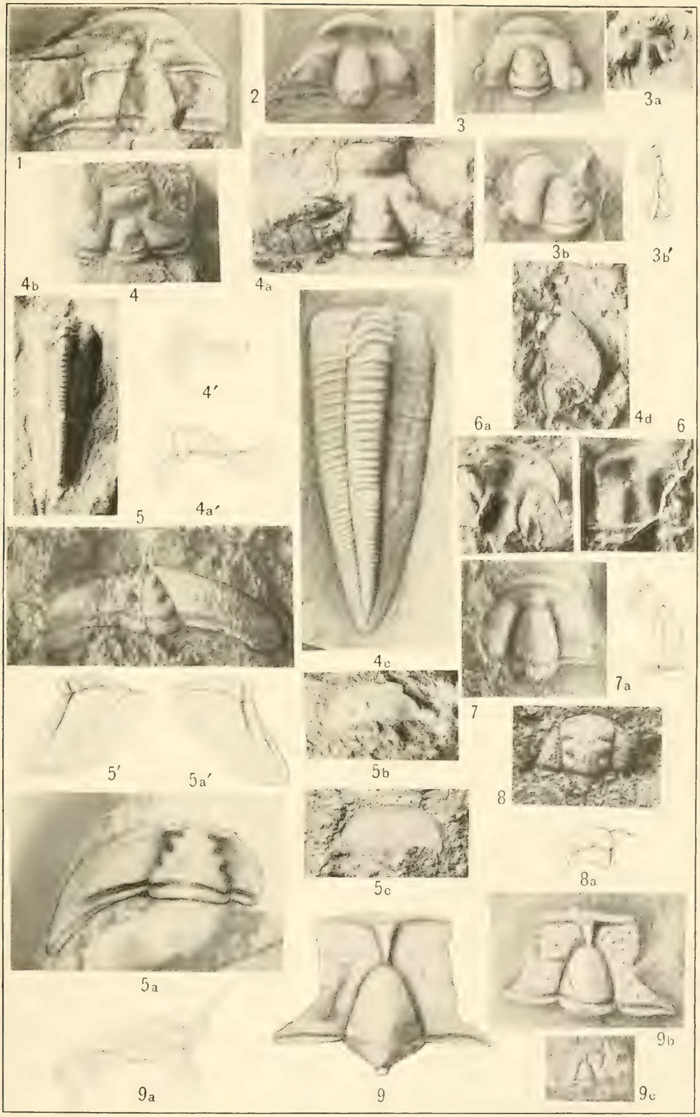
4c. (× 2.) Same as fig. *4b* with photograph retouched to bring out thoracic segments.

4d. (× 2.) Free cheek associated with the specimen represented by fig. *4a*. U. S. National Museum, Catalogue No. 61584.

The specimens illustrated by figs. 4, *4a-d* are all from the Eau Claire formation of the Upper Cambrian. Fig. 4, from locality 100, near Menomonie, and figs. *4a* and *4d* from locality 83a, Rock Falls, both in Dunn County, Wisconsin. Figs. *4b-c* are from locality 98, near Eau Claire, Eau Claire County, Wisconsin.

Dresbachia amata Walcott 167

FIGS. 5, 5′. (× 4.) Dorsal view and side outline of a cranidium, preserving the projecting frontal rim with its deep median furrow. U. S. National Museum, Catalogue No. 61585.



CAMBRIAN TRILOBITES

Dresbachia amata Walcott—Continued. PAGE

5*a*, 5*a'*. (× 4.) Dorsal view and side outline of a broken cranidium. U. S. National Museum, Catalogue No. 61586.

5*b*. (× 2.) Free cheek associated with cranidia of this species. U. S. National Museum, Catalogue No. 61587.

5*c*. (× 2.) A narrow form of free cheek associated with cranidia of this species. U. S. National Museum, Catalogue No. 61588.

The specimens represented by figs. 5 and 5*a* are from locality **79x**, north of Galesville, Trempealeau County, Wisconsin. The specimen represented by fig. 5*b* is from locality 84, Dresbach, Winona County Minnesota, and 5*c*, from **98x**, Eau Claire, Eau Claire County, Wisconsin. All are from the Upper Cambrian, Eau Claire formation of Wisconsin and Minnesota.

Alokistocare ticida Walcott.. 187

FIG. 6. (Natural size.) A broken, weather-worn cranidium. U. S. National Museum, Catalogue No. 61589.

6*a*. (Natural size.) Interior surface of a broken cranidium. U. S. National Museum, Catalogue No. 61590.

The specimens represented by figs. 6 and 6*a* are from locality **55s**, Middle Cambrian: Bloomington formation, Blacksmith Fork Canyon, Cache County, Utah.

Acrocephalites ? glomeratus Walcott 179

FIGS. 7, 7*a*. (Natural size.) Top view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 61591.

From locality 340c, Upper Cambrian: Rawlins, Carbon County, Wyoming.

Amphion ? matutina Hall.. 219

FIGS. 8, 8*a*. (× 4.) Dorsal view and side outline of a cranidium. U. S. National Museum, Catalogue No. 61592.

The specimen illustrated is from locality 84, Upper Cambrian: Eau Claire formation; Dresbach, Winona County, Minnesota.

Acrocephalites ? aster Walcott....................................... 178

FIGS. 9, 9*a*. (× 3.) Top view and side outline. The side outline from the occipital segment is traced from a second specimen. U. S. National Museum, Catalogue No. 61593.

From locality 107c, Upper Cambrian: Maryville limestone; 11 miles northwest of Knoxville, Tennessee.

9*b*. (× 3.) Cranidium compressed in shale. It shows tubercles more strongly than the specimen represented by fig. 9, which occurs in limestone. U. S. National Museum, Catalogue No. 61594.

9*c*. (Natural size.) This is the same specimen as that represented by fig. 9*b*.

The specimen represented by figs. 9*b* and 9*c* is from locality 358e, Upper Cambrian: Conasauga formation; Birmingham City, Alabama.

DESCRIPTION OF PLATE 27

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Norwoodia saffordi Walcott.. 171

Fig. 1. (× 4.) Portion of cranidium showing glabellar furrows. U. S. National Museum, Catalogue No. 61595.

1*a*. (× 4.) Broken and compressed cranidium. U. S. National Museum, Catalogue No. 61596.

1*b*. (× 3.) Free cheek. U. S. National Museum, Catalogue No. 61597.

1*c*. (× 4.) A small, almost entire cranidium. U. S. National Museum, Catalogue No. 61598.

1*d*. (× 4.) A nearly entire dorsal shield with eight thoracic segments. U. S. National Museum, Catalogue No. 61599.

1*e*. (× 4.) Pygidium associated with this species. U. S. National Museum, Catalogue No. 61600.

1*f*. Diagrammatic side outline of cranidium.

All of the specimens illustrated are from the Middle Cambrian: (103, 103a) Rome formation, south of Rogersville, Hawkins County, Tennessee.

Norwoodia gracilis Walcott.. 169

Fig. 2. (× 4.) Entire dorsal shield as photographed and drawn from an imperfect specimen with damaged portions restored from associated specimens. U. S. National Museum, Catalogue No. 61601.

2*a* (× 3) and 2*b* (× 5). Cranidia illustrating form. Fig. 2*b* is a younger stage of growth. U. S. National Museum, Catalogue Nos. 61602 and 61603.

2*c*. (× 4.) Ventral side of a distorted cephalon. U. S. National Museum, Catalogue No. 61604.

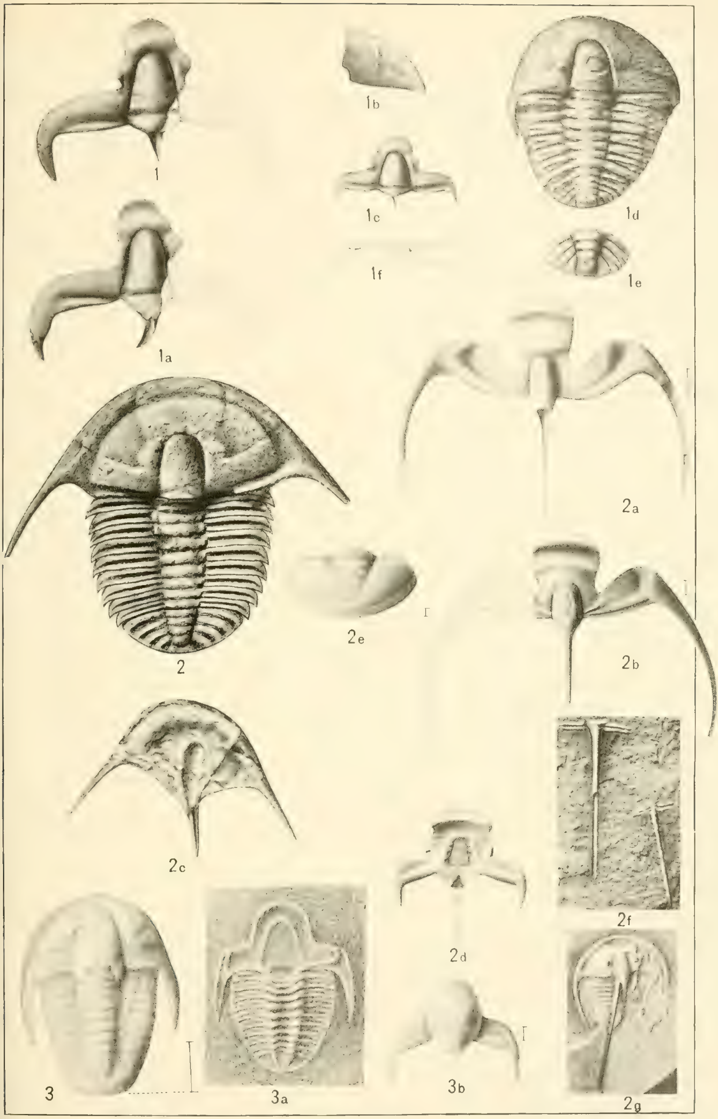
2*d*. (× 4.) Ventral side of a small cranidium. U. S. National Museum, Catalogue No. 61605.

2*e*. (× 8.) A small pygidium associated with specimens represented by figs. 2*a-b*. U. S. National Museum, Catalogue No. 61606.

2*f*. (× 2.) Thoracic median spines. U. S. National Museum, Catalogue No. 61607.

2*g*. (× 3.) Cranidium and a long thoracic median spine. U. S. National Museum, Catalogue No. 61608.

All the specimens illustrated are compressed in the Upper Cambrian fine Conasauga shale as they occur at (90a) Cedar Bluff and (92x) Yanceys Bend, on the Coosa River, Cherokee County, Alabama.



NORWOODIA

PAGE

Norwoodia simplex Walcott.. 171

FIG. 3. (× 4.) An entire, slightly weathered specimen of the dorsal shield. U. S. National Museum, Catalogue No. 61609.

3*a*. (× 6.) Interior of a compressed dorsal shield. U. S. National Museum, Catalogue No. 61610.

3*b*. (× 6.) An imperfect, small cranidium preserving something of its original convexity. U. S. National Museum, Catalogue No. 61611.

All the specimens illustrated are from localities 90a and 91, Upper Cambrian: Conasauga shale; at Cedar Bluff, Coosa River, Cherokee County, Alabama.

DESCRIPTION OF PLATE 28

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Norwoodia ponderosa Walcott.................................... 171

Fig. 1. (× 6.) Matrix of a cranidium compressed in fine shale. The occipital spine is restored. U. S. National Museum, Catalogue No. 61612.

1*a*. (× 5.) Cranidium varying in form from fig. 1. U. S. National Museum, Catalogue No. 61613.

1*b*. (× 6.) Minute pygidium associated with this species. U. S. National Museum, Catalogue No. 61614.

The specimens illustrated by figs. 1, 1*a-b* are from the Upper Cambrian: (90a) Conasauga shale; Cedar Bluff on Coosa River, Cherokee County, Alabama.

Norwoodia tenera Walcott.................................... 172

Fig. 2. (× 6.) Small cranidium. U. S. National Museum, Catalogue No. 61615.

2*a*. (× 6.) Dorsal view of a small dorsal shield with seven thoracic segments. U. S. National Museum, Catalogue No. 61616.

2*b*. (× 6.) Dorsal shield with eight thoracic segments. U. S. National Museum, Catalogue No. 61617.

2*c*. (× 8.) Minute cranidium. U. S. National Museum, Catalogue No. 61618.

2*d*. (× 6.) A detached median thoracic spine. U. S. National Museum, Catalogue No. 61619.

2*c*. (× 4.) A broken dorsal shield on which there is a thoracic segment with a median spine attached. U. S. National Museum, Catalogue No. 61620.

2*f*. (× 4.) A very minute cranidium beside a larger form. U. S. National Museum, Catalogue No. 61621.

2*g*. (× 4.) Side outline of larger cranidium represented by fig. 2*f*.

The specimens illustrated are from locality 30n, Upper Cambrian: Weeks formation, Weeks Canyon, House Range, Millard County, Utah.

Millardia semele Walcott.................................... 166

Fig. 3. (× 4.) Small cranidium showing tuberculated frontal rim. U. S. National Museum, Catalogue No. 61622.

3*a*. (× 4.) Ventral surface of a cephalon. U. S. National Museum, Catalogue No. 61623.

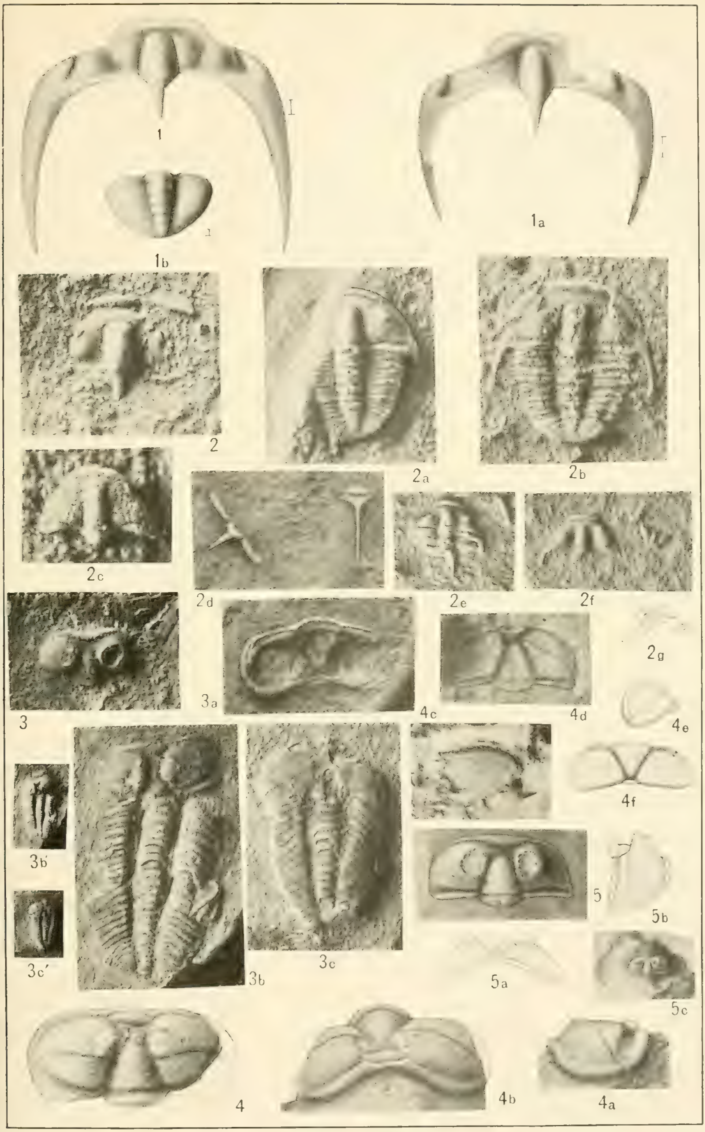
3*b*. (× 4.) Dorsal shield with 23 thoracic segments. U. S. National Museum, Catalogue No. 61624.

3*b*′. (Natural size.) The same specimen as that represented by fig. 3*b*.

3*c*. (× 4.) Compressed dorsal shield on surface of shaly limestone. U. S. National Museum, Catalogue No. 61625.

3*c*′. (Natural size.) The same specimen as that represented by fig. 3*c*.

The specimens illustrated are from locality 30 o, as given above under figs. 2, 2*a-g*.



CAMBRIAN TRILOBITES

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Millardia optata (Hall) 165

FIGS. 4, 4*a*, 4*b*. (× 4.) Top, side, and front view of a small entire cranidium. U. S. National Museum, Catalogue No. 61626.

4*c*. (× 2.) Free cheek associated with the specimen represented by fig. 4. U. S. National Museum, Catalogue No. 61627.

4*d*, 4*e*, 4*f*. (× 4.) Top, side, and front views of a small entire cranidium. U. S. National Museum, Catalogue No. 61628.

The specimens represented by figs. 4, 4*a-f* are from locality 79c, Eau Claire formation, near Hudson, St. Croix County, Wisconsin.

Millardia avitas Walcott 165

FIGS. 5, 5*a*, 5*b*. (× 4.) Top view of type specimen of cranidium, with outline of front and side views. U. S. National Museum, Catalogue No. 61629.

5*c*. (Natural size.) This is the same specimen as that represented by fig. 5.

The specimen represented by figs. 5, 5*a-c* is from locality 107k, Upper Cambrian: Buffalo Run limestone, 2 miles north of Benore Post Office, Center County, Pennsylvania.

DESCRIPTION OF PLATE 29

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Crepicephalus iowensis (Owen) 207

FIG. 1. (Natural size.) Restored figures of entire dorsal shield based on left half of a nearly entire specimen, and associated cranidium and pygidium. U. S. National Museum, Catalogue No. 61630.

2. (Natural size.) Fragment of a thorax preserving 11 segments with prolonged pleura. U. S. National Museum, Catalogue No. 61631.

2a, 2a'. (Natural size.) Broken cranidium with profile. U. S. National Museum, Catalogue No. 61632.

2b. (Natural size.) Pygidium with the outer border exfoliated. U. S. National Museum, Catalogue No. 61633.

Figures *2a* and *2b* are of material collected by Owen.

2c. (Natural size.) Free cheek with long genal spines. U. S. National Museum, Catalogue No. 61634.

2d. (Natural size.) Small, nearly entire pygidium. U. S. National Museum, Catalogue No. 61635.

2e. (Natural size.) Hypostoma. U. S. National Museum, Catalogue No. 61637.

2f. (Natural size.) Cranidium of the characteristic form as it occurs in the Eau Claire sandstones. U. S. National Museum, Catalogue No. 61636.

The specimens represented by figs. 1, *2d*, and *2f* are from (78a) the Eau Claire formation, Eau Claire, Wisconsin.

Those represented by 2, *2a-c*, and *2e* are from the Eau Claire formation at Dresbach, Minnesota, opposite the mouth of Black River.

Crepicephalus texanus danace Walcott 214

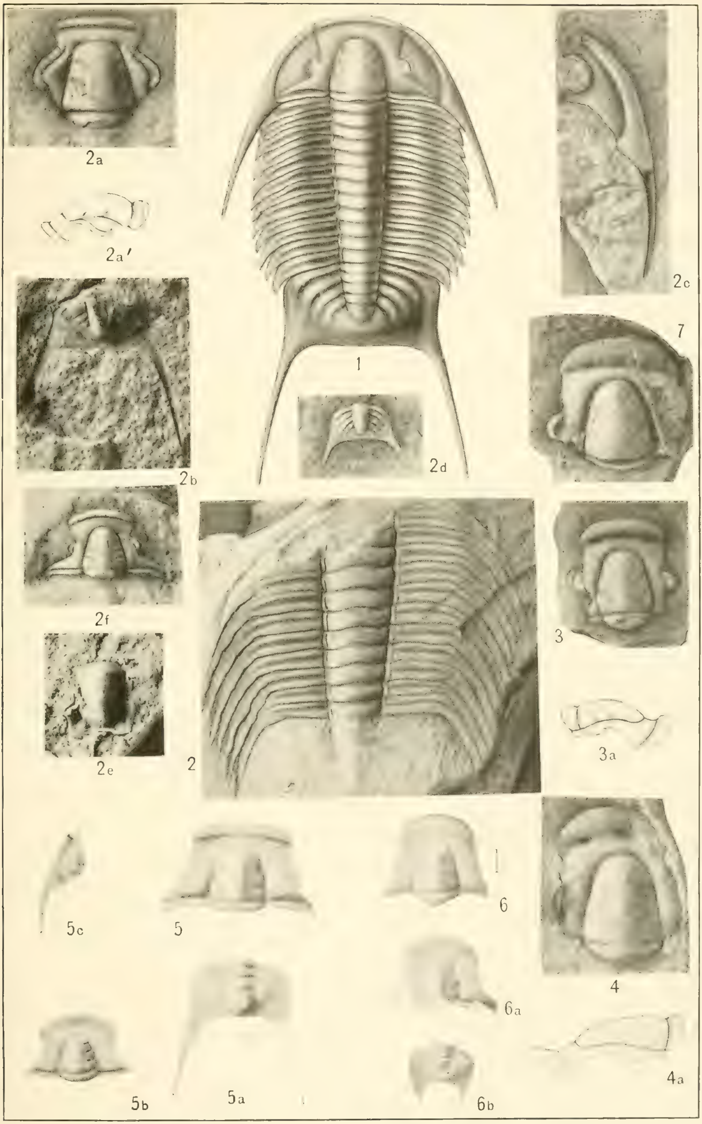
FIGS. 3, *3a*. (Natural size.) Broken cranidium and longitudinal profile of the only specimen in the collections. U. S. National Museum, Catalogue No. 61638.

From locality 79d, Eau Claire formation, near Eau Claire, Wisconsin.

Crepicephalus texanus elongatus Walcott 214

FIGS 4, *4a*. (Natural size.) Dorsal view and longitudinal profile of a fragmentary cranidium. U. S. National Museum, Catalogue No. 61639.

From locality 79e, Eau Claire formation, 1 mile (1.6 km.) north of Eleva, Wisconsin.



CREPICEPHALUS

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Crepicephalus liliana Walcott 209

FIG. 5. (Natural size.) Cranidium with granulose surface. U. S. National Museum, Catalogue No. 15428.

5*a*. (Natural size.) Pygidium associated with the specimen represented by fig. 5 in the same fragment of rock. U. S. National Museum, Catalogue No. 15428.

5*b*. (Natural size.) Cranidium from another locality. U. S. National Museum, Catalogue No. 61640.

5*c*. (Natural size.) Free cheek associated with the cranidium of 5*b*. U. S. National Museum, Catalogue No. 61641.

The specimens represented by figs. 5 and 5*a* are from 31a, Lower Cambrian: Pioche formation, near Pioche, Nevada.

The specimens represented by figs. 5*b* and 5*c* are from (30) Lower Cambrian: limestone on west slope of Highland Range, 8 miles (12.8 km.) north of Bennetts Spring, Nevada.

These figures are illustrated in the Tenth Annual Report, U. S. Geol. Survey, 1890, plate 96, figs. 7, 7*a-c*.

Crepicephalus augusta Walcott 204

FIG. 6. (× 4.) A small cranidium, showing variation of form from that represented by fig. 6*a*. U. S. National Museum, Catalogue No. 61642.

6*a*. (Natural size.) Broken cranidium showing form of frontal border. U. S. National Museum, Catalogue No. 61643.

6*b*. (Natural size.) Pygidium with right side partly restored. U. S. National Museum, Catalogue No. 15430.

The two cranidia represented by figs. 6 and 6*a* are from (30) Lower Cambrian: limestone on west slope of Highland Range, 8 miles (12.8 km.) north of Bennetts Spring, Nevada.

The specimen represented by fig. 6*b* is from (31a) Lower Cambrian: Pioche formation, near Pioche, Nevada.

Specimens of the pygidium also occur in locality 30.

These figures are illustrated in the Tenth Annual Report, U. S. Geol. Survey, 1890, plate 96, figs. 9, 9*a-b*.

Crepicephalus texanus (Shumard). (See pl. 30) 209

FIG. 7. (Natural size.) Cranidium with occipital ring restored, and associated specimen. U. S. National Museum, Catalogue No. 61644.

From locality 151 i, Gallatin limestone; northeast of White Sulphur Springs, Meagher County, Montana.

DESCRIPTION OF PLATE 30

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Crepicephalus texanus (Shumard). (See pl. 29, fig. 7) 209

FIG. 1. (Natural size.) Partly restored figure. Entire specimens with the genal and pygidium spines occur in large numbers. This figure is illustrated in Monograph 32, U. S. Geological Survey, 1892, Part 2, plate 65, fig. 5. U. S. National Museum, Catalogue No. 35232.

1*a*. (Natural size.) Inner side of a pygidium, showing the manner in which the two spines are attached to the pygidium. U. S. National Museum, Catalogue No. 61645.

1*b*. (Natural size.) Small cranidium with broad glabella. U. S. National Museum, Catalogue No. 61646.

All of the specimens used in the restoration of fig. 1 and in figs. 1*a* and 1*b* are from Upper Cambrian, (90a, 91) the Conasauga shales at Cedar Bluff, Alabama.

2, 2′. (× 1.5.) Top view and side outline of a broken cranidium, the broken portions of which have been restored in the outline. U. S. National Museum, Catalogue No. 61647.

2*a*. (Natural size.) Front portion of cranidium, showing frontal limb and narrow, nearly flat frontal border. U. S. National Museum, Catalogue No. 61648.

2*b*. (Natural size.) Fragment of a cranidium with the outline of broken portions restored. U. S. National Museum, Catalogue No. 61649.

2*c*. (Natural size.) Matrix and spine of a broken pygidium. U. S. National Museum, Catalogue No. 61650.

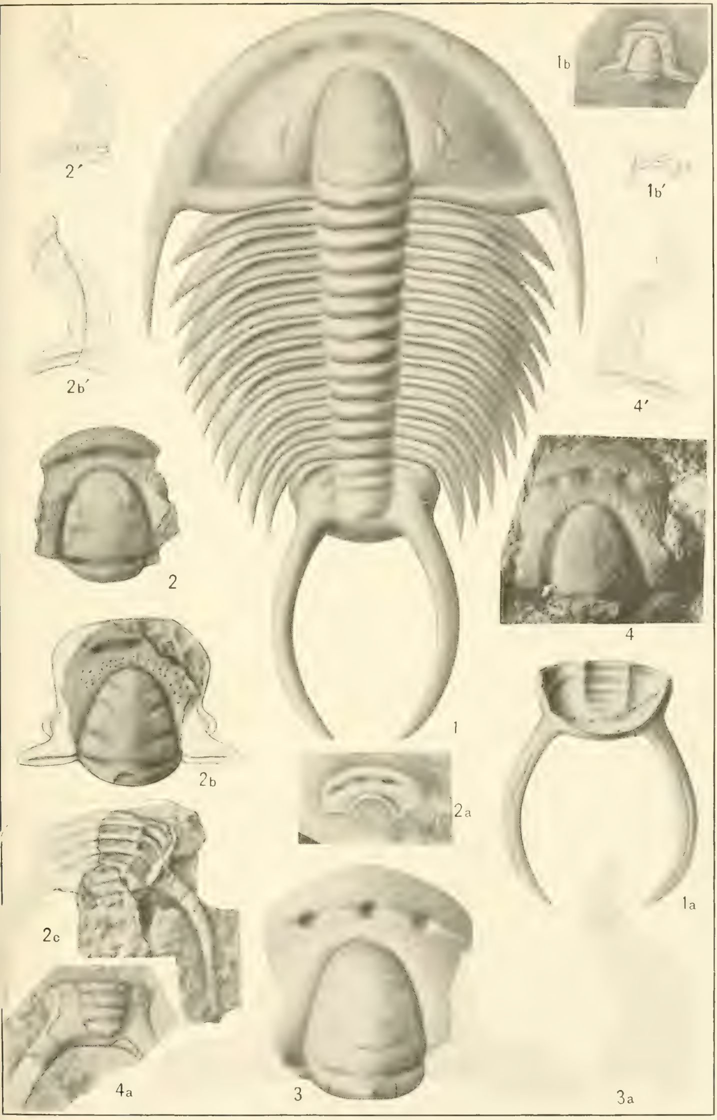
The three specimens illustrated by figs. 2, 2*a-c* are from (67a) the Cap Mountain limestone, at the head of Clear Creek on Potatotop, Burnet County, Texas.

3, 3*a*. (Natural size.) Top view and side outline of a large cranidium from limestone interbedded in the Conasauga shale, (89) Murphrees Valley, Blount County, Alabama. U. S. National Museum, Catalogue No. 61651.

4, 4′. (× 1.5.) Dorsal view and profile outline of nearly entire cranidium. U. S. National Museum, Catalogue No. 61652.

4*a*. (× 1.5.) Narrow form of pygidium tentatively referred to this species. U. S. National Museum, Catalogue No. 61653.

The specimens represented by figs. 4 and 4*a* are from locality **151b**, Gallatin limestone, between Pebble Creek and Soda Butte Creek, Yellowstone National Park, Wyoming.



CREPICEPHALUS TEXANUS (Shumard)

DESCRIPTION OF PLATE 31

PAGE

Crepicephalus thoosa Walcott 214

FIG. 1. (Natural size.) Dorsal and side view of type specimen of the cranidium. U. S. National Museum, Catalogue No. 61654.

From (125a) Maryville limestone, Big Creek, northeast of Rogersville, Hawkins County, Tennessee.

1*a*, 1*a'*. (Natural size.) Top view and profile of a large broken cranidium. The broken parts restored in outline. U. S. National Museum, Catalogue No. 61655. (Locality 119.)

1*b*. (× 2.) Free cheek associated with the cranidia of this species. U. S. National Museum, Catalogue No. 61656. (Locality 107.)

1*c*. (× 3.) Small cranidium enlarged to illustrate pustulose surface and form. Broken portions restored in outline from fig. 1. U. S. National Museum, Catalogue No. 61657.

From (119a) Honaker (= Maryville) limestone, east of Greendale, Washington County, Virginia.

1*d*. (× 2.) Hypostoma associated with this species at locality 119. U. S. National Museum, Catalogue No. 61658.

The specimens represented by figs. 1*a* and 1*d* are from Upper Cambrian, (119) Maryville limestone; beneath Nolichucky shale, Cub Creek, southeast of Morristown, Hamblen County, Tennessee.

1*e*. (× 2.) Hypostoma associated with this species at locality 107. U. S. National Museum, Catalogue No. 61659.

1*f*. (Natural size.) Dorsal view of pygidium and side outline associated with cranidia of this species at locality 107. U. S. National Museum, Catalogue No. 61660.

The specimens represented by figs. 1*b*, 1*e*, and 1*f* are from Maryville limestone, (107) Bull Run Ridge, northwest of Knoxville, Knox County, Tennessee.

1*g*. (× 2.) Pygidium associated with this species at locality 145a. U. S. National Museum, Catalogue No. 61661.

1*h*. (× 6.) Enlargement of surface to illustrate granulation.

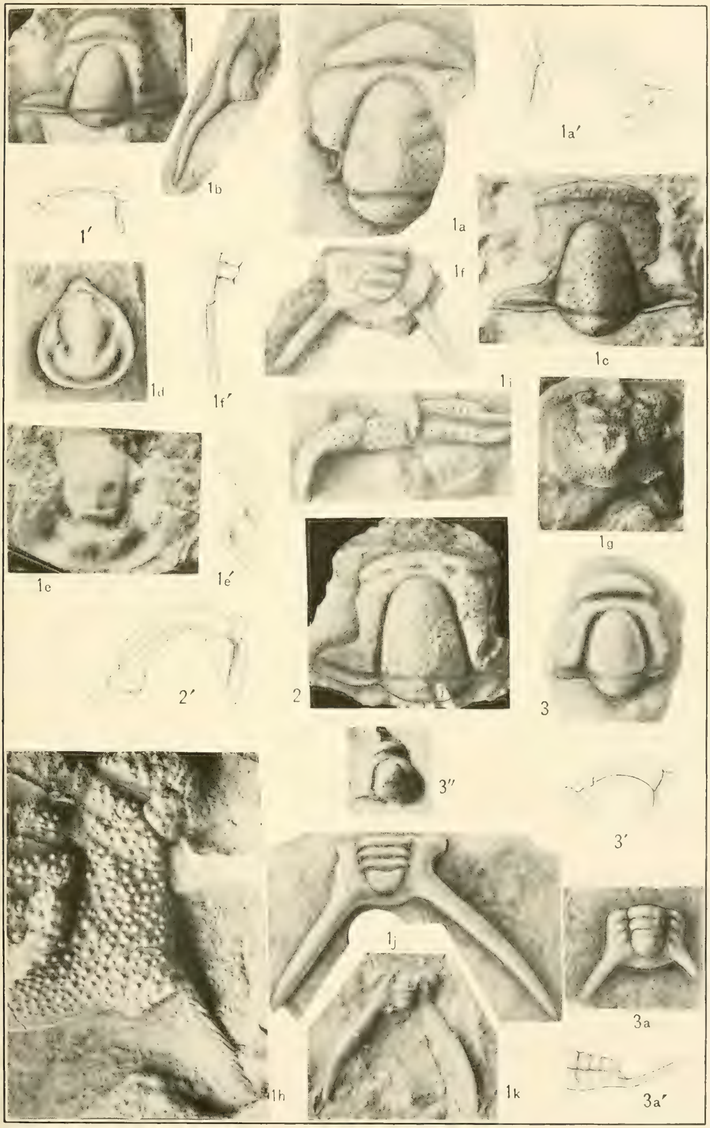
1*i*. (× 3.) Broken thoracic segment, to illustrate granulation. U. S. National Museum, Catalogue No. 61662.

The specimens represented by figs. 1*g* and 1*i* are from Upper Cambrian, (145a) Conasauga shale; upper part of shale beneath Knox dolomite; east of Gaylesville, Cherokee County, Alabama.

1*j*. (× 2.) Small pygidium weathered out on limestone. U. S. National Museum, Catalogue No. 61663.

1*k*. (Natural size.) Large pygidium associated with specimen represented by fig. 1*j*. U. S. National Museum, Catalogue No. 61664.

The specimens represented by figs. 1*j* and 1*k* are from locality 91, Upper Cambrian: Conasauga formation; Cedar Bluff, Cherokee County, Alabama.



CREPICEPHALUS

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Crepicephalus tumidus Walcott.. 217

FIG. 2. (Natural size.) Dorsal and side view of the type cranidium of the species. The broken parts are restored in outline. U. S. National Museum, Catalogue No. 61665. (Locality 120.)

Crepicephalus comus Walcott.. 205

FIG. 3. ($\times$ 2.) Dorsal and side view of the type cranidium. U. S. National Museum, Catalogue No. 61666. (Locality 120.)

3*a*. (Natural size.) Pygidium. U. S. National Museum, Catalogue No. 61667. (Locality 107.)

The specimens represented by figs. 2 and 3 are from locality 120, Upper Cambrian: Maryville limestone; north of Bays Mountain, on Beaver Creek, Sevier County, 18 miles east-northeast of Knoxville, Knox County, Tennessee.

Fig. 3*a* is from locality 107, Upper Cambrian: Maryville limestone, Bull Run Ridge, northwest of Knoxville, Knox County, Tennessee.

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Crepicephalus dis Walcott.. 207

FIG. 1. (× 1.5.) Dorsal view of cranidium. U. S. National Museum, Catalogue No. 61668.

1a. (Natural size.) Associated free cheek. U. S. National Museum, Catalogue No. 61669.

1b, 1b′. (× 2.) Dorsal and side views of a slightly distorted cranidium. U. S. National Museum, Catalogue No. 61670.

1c. (Natural size.) Pygidium associated with specimen represented by figs. 1, *1a-b*. U. S. National Museum, Catalogue No. 61671.

The specimens represented by figs. 1, *1a-c* are from localities 14v, 30n, and 30o, Upper Cambrian: Weeks formation; House Range, Utah.

Crepicephalus camiro Walcott.. 205

FIGS. 2, 2′. (× 2.) Dorsal view and side outline of type specimen of cranidium. U. S. National Museum, Catalogue No. 61672.

2″. (Natural size.) This is the same specimen as fig. 2.

2a, 2a′. (× 2.) Dorsal view and side outline of a pygidium associated with this species. U. S. National Museum, Catalogue No. 61673.

The specimens represented by figs. 2 and *2a* are from locality 120, Upper Cambrian: Maryville limestone; 18 miles east-northeast of Knoxville, Tennessee.

Crepicephalus coosensis Walcott.. 206

FIG. 3. (Natural size.) Restored figure of dorsal shield based on a large specimen preserving the cranidium, thorax, and pygidium in an imperfect condition. U. S. National Museum, Catalogue No. 61674.

3a, 3a′. (Natural size.) Dorsal view and side outline of a large cranidium. U. S. National Museum, Catalogue No. 61675.

3b. (Natural size.) Dorsal view of large pygidium. U. S. National Museum, Catalogue No. 61676.

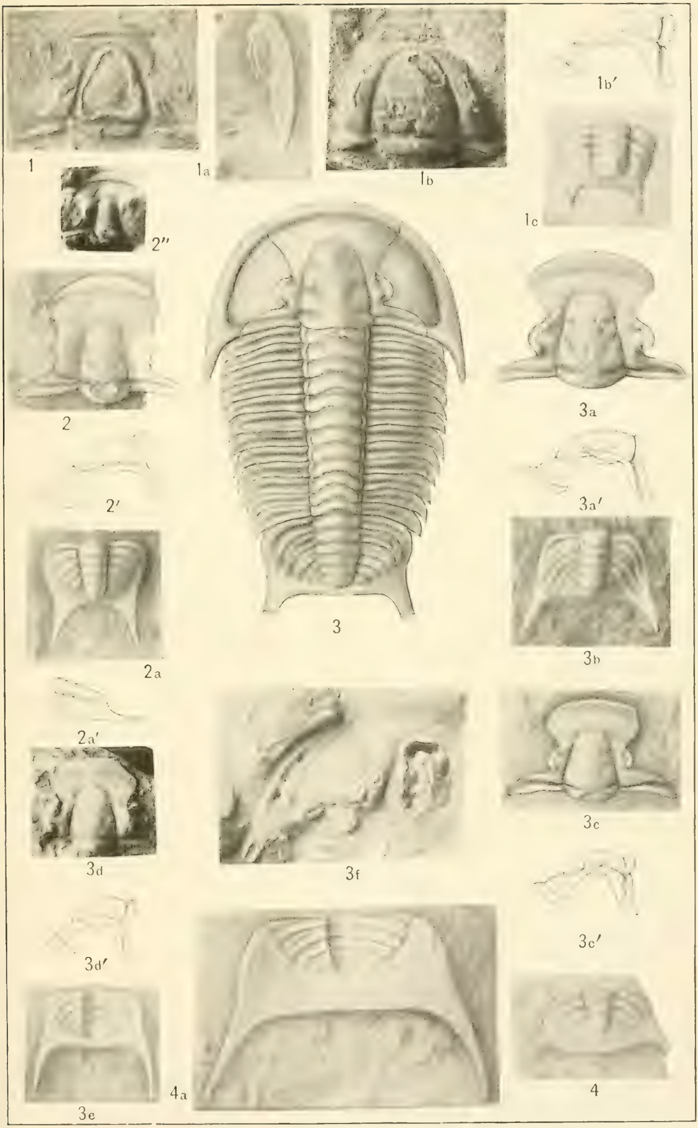
3c, 3c′. (Natural size.) Dorsal view and side outline of a medium-sized cranidium. The broken parts are restored in outline. U. S. National Museum, Catalogue No. 61677.

3d, 3d′. (Natural size.) Dorsal view and side outline of a cranidium, showing palpebral lobe and occipital ring. U. S. National Museum, Catalogue No. 61678.

3e. (Natural size.) Interior view of a pygidium showing portions of the doublure. U. S. National Museum, Catalogue No. 61679.

3f. (× 2.) Cranidium and left free cheek. U. S. National Museum, Catalogue No. 61680.

The specimens represented by figs. 3, *3a-c* are from locality 90x, Middle Cambrian: lower part of Conasauga formation; east of Center, Cherokee County, Alabama.



CREPICEPHALUS

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Crepicephalus sp. undt (1) 218

FIG. 4. (Natural size.) Dorsal view of a pygidium. U. S. National Museum, Catalogue No. 61681.

From Upper Cambrian: (107) Maryville limestone; 11 miles (17.6 km.) northwest of Knoxville, Tennessee.

4*a*. (Natural size.) Interior of a large pygidium. U. S. National Museum, Catalogue No. 61682.

From Upper Cambrian: (16) thin, slabby limestone of Conasauga formation; Murphrees Valley, Blount County, Alabama.

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Crepicephalus tripunctatus (Whitfield) 215

FIGS. 1, *1a*. (× 1.5.) Dorsal and side views of a cranidium which is the type of the species. U. S. National Museum, Catalogue No. 26934.

1b. (× 1.5.) Free cheek associated with fig. 1. U. S. National Museum, Catalogue No. 26934.

The specimens represented by figs. 1, *1a-b* are from the Upper Cambrian: (358d) Gallatin limestone; Meagher County, Montana.

Crepicephalus tripunctatus magnispinus Walcott 216

FIGS. 2, *2a*. (× 1.5.) Dorsal and side views of a typical cranidium. U. S. National Museum, Catalogue No. 61684.

2b. (Natural size.) Side view of a broken cranidium having a very large occipital spine. U. S. National Museum, Catalogue No. 61685.

2c. (Natural size.) Dorsal and side views of a pygidium referred to this species. U. S. National Museum, Catalogue No. 61686.

The specimens represented by figs. 2, *2a-c* are from locality 107, Maryville limestone; 11 miles northwest of Knoxville, Tennessee.

Crepicephalus coria Walcott 206

FIG. 3. (Natural size.) Interior of a fragmentary specimen, showing 14 segments in the thorax. U. S. National Museum, Catalogue No. 61687.

3a, 3a'. (Natural size.) Dorsal and side views of a small, slightly crushed cranidium. U. S. National Museum, Catalogue No. 61688.

3b. (× 2.) Dorsal view of a small convex cranidium. U. S. National Museum, Catalogue No. 61689.

3c. (Natural size.) A large cranidium illustrating slight change in form with increase in size. U. S. National Museum, Catalogue No. 61690.

3d. (Natural size.) Associated free cheek. U. S. National Museum, Catalogue No. 61691.

3e. (Natural size.) Dorsal view of a broken pygidium. U. S. National Museum, Catalogue No. 61692.

3f. (Natural size.) Interior of a pygidium. U. S. National Museum, Catalogue No. 61693.

3g. (× 2.) Dorsal view of a small pygidium. U. S. National Museum, Catalogue No. 61694.

The specimens represented by figs. 3, *3a-g* are from locality 30n, Upper Cambrian: Weeks formation; House Range, Utah.

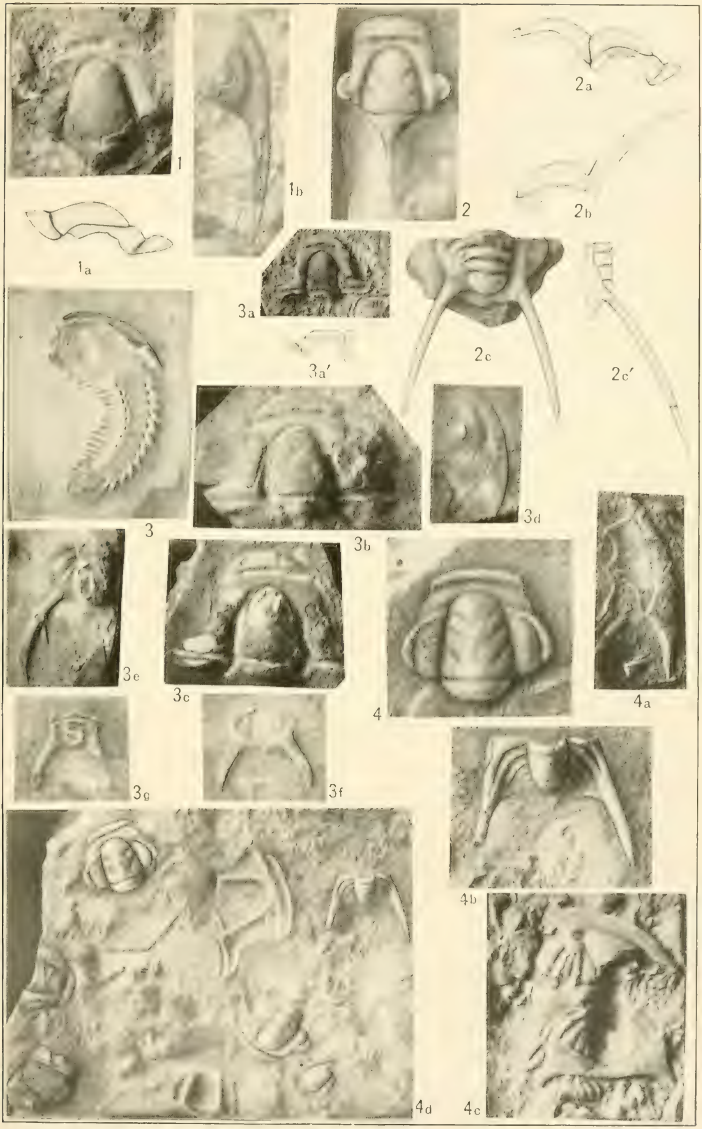

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FIG. 4. (×2.) Cranidium with broken front border restored from associated specimens. U. S. National Museum, Catalogue No. 61695.

4*a*. (×2.) Under side of associated free cheek. U. S. National Museum, Catalogue No. 61696.

4*b*. (×2.) Pygidium associated with fig. 1. U. S. National Museum, Catalogue No. 61697.

4*c*. (×2.) Under side of an associated pygidium. U. S. National Museum, Catalogue No. 61698.

4*d*. (Natural size.) Fragment of weathered shaly limestone on which several cranidia occur and the pygidium represented by fig. 4*b*.

The specimens represented by figs. 4, 4*a-d* are from locality 150b, Upper Cambrian: Gallatin limestone; at head of White Creek, Lewis and Clark National Forest, Montana.

DESCRIPTION OF PLATE 34

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Lonchocephalus pholus Walcott 194

FIG. 1. (× 4.) Interior of cranidium. U. S. National Museum, Catalogue No. 61699.

1*a*, 1*a'*. (× 4.) Exterior of cranidium and side outline. U. S. National Museum, Catalogue No. 61700.

1*b*. (× 4.) Cranidium preserving relief of glabella and strong occipital spine. There is also a cranidium of *Norwoodia tenera* on the same piece of limestone. U. S. National Museum, Catalogue No. 61701.

Lonchocephalus plena Walcott 194

FIG. 2. (× 6.) Dorsal view and side outline of a broken cephalon. U. S. National Museum, Catalogue No. 61702.

2*a*. (× 6.) A cranidium preserving the glabella and fixed cheek. U. S. National Museum, Catalogue No. 61703.

The specimens represented by figs. 1, 1*a*-*b*, 2, and 2*a* are from a shaly limestone, (30n) Upper Cambrian: Weeks formation, House Range, Utah.

Lonchocephalus chippewaensis Owen. (See pl. 37) 190

FIG. 3. (× 2.) Surface of sandstone with cranidia and pygidia. A cranidium of *Pagodia thea* Walcott and fragments of *Hyolithes primordialis* Hall occur in the sandstone. (See plate 37.)

3*a*. (× 6.) A nearly entire dorsal shield with the weathered surface restored from other specimens. U. S. National Museum, Catalogue No. 61704.

The specimen represented by fig. 3 is from locality 98, Upper Cambrian: Eau Claire formation; near Eau Claire, Eau Claire County (collected by Dr. Samuel Weidman, and now in collection of Geological Survey of Wisconsin at Madison); that represented by fig. 3*a* is from locality 82, St. Croix Falls, Polk County; both in Wisconsin.

Lonchocephalus minutus (Bradley) 193

FIGS. 4, 4*a*. (× 3.) Dorsal and side views of a convex cranidium. U. S. National Museum, Catalogue No. 58566.

4*b*. (× 3.) Associated free cheek. U. S. National Museum, Catalogue No. 58567.

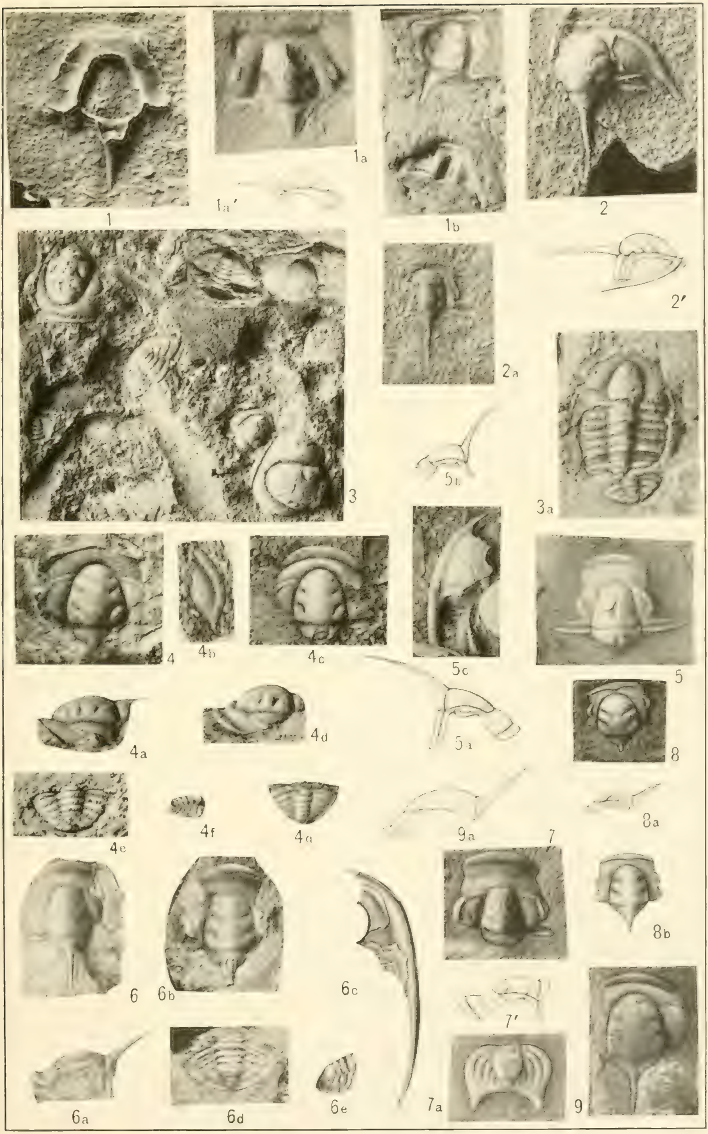
4*c*, 4*d*. (× 3.) Dorsal and side views of a cranidium preserving the anterior rim and border. U. S. National Museum, Catalogue No. 58568.

4*e*, 4*f*. (× 3.) Dorsal and side views of a pygidium from which the test has been exfoliated. U. S. National Museum, Catalogue No. 58569.

4*g*. (× 3.) Dorsal view of a pygidium preserving the test. U. S. National Museum, Catalogue No. 58570.

The specimens represented by figs. 4, 4*a*-*g* are from locality 77, Upper Cambrian: Potsdam horizon; sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70-75 feet (21.3-22.9 m.) above the water in Ausable Chasm, Essex County, New York.

The above illustrations are taken from Smithsonian Miscellaneous Collections, Vol. 57, 1914, pl. 43, figs. 21-24.



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Saratogia wisconsensis (Owen) 198

Fig. 5. (Natural size.) Cranidium with occipital spine broken off.

5*a*. (Natural size.) Side outline of fig. 5.

5*b*. (× 2.) Side view of a small cranidium.

5*c*. (Natural size.) Free cheek.

The specimens represented by figs. 5, 5*a-c*, are from locality 151e, Upper Cambrian: Gallatin limestone; Yellowstone National Park, Wyoming.

These specimens are associated on a slab of limestone (U. S. National Museum, Catalogue No. 35225) and are the same that are illustrated by woodcut prints on plate 64, figs. 1, 1*a*, Monogr. 32, U. S. Geol. Survey. By error, in making up that plate, a figure of *Saratogia hamulus* (Owen), fig. 1*b*, and of the pygidium of *Ptychoparia diademata* (Hall), fig. 1*c*, was included under this species.

Saratogia calcifera (Walcott) 197

Figs. 6, 6*a*. (Natural size.) Dorsal and side views of an imperfect cranidium. U. S. National Museum, Catalogue No. 58554.

6*b*. (Natural size.) Dorsal view of a cranidium, showing the characters of the glabella. U. S. National Museum, Catalogue No. 58555.

6*c*. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58556.

6*d*, 6*e*. (× 2.) Dorsal view and side outline of pygidium associated with this species. U. S. National Museum, Catalogue No. 58557.

The specimens represented by figs. 6, 6*a-e* are from locality 76, Upper Cambrian: Hoyt limestone; Hoyts quarry, 4 miles (6.4 km) west of Saratoga Springs, Saratoga County, New York.

The above illustrations are taken from Smithsonian Miscellaneous Collections, Vol. 57, 1914, pl. 43, figs. 7, 7*a*-10*a*.

Crepicephalus unzia Walcott 217

Fig. 7, 7′. (× 2.) Dorsal view and side profile of a cranidium. U. S. National Museum, Catalogue No. 61705.

7*a*. (× 3.) A small pygidium with front outline restored. U. S. National Museum, Catalogue No. 61706.

The specimens represented by figs. 7 and 7*a* are from locality 150b, Upper Cambrian: Gallatin limestone; head of White Creek, Lewis and Clark National Forest, Montana.

Lonchocephalus minor (Shumard) 192

Figs. 8, 8*a*. (× 4.) Dorsal view and side outline of a typical cranidium. U. S. National Museum, Catalogue No. 61707.

8*b*. (× 4.) Pencil drawing of specimen represented by photograph in fig. 8.

From locality 84, Upper Cambrian: Eau Claire formation; Dresbach, Minnesota.

Lonchocephalus bunus Walcott 190

Figs. 9, 9*a*. (× 3.) Dorsal and side views of typical cranidium. U. S. National Museum, Catalogue No. 61708.

The specimen represented by fig. 9 is from locality 99, Upper Cambrian: Franconia formation; near Winona, Minnesota. Collected by Mr. W. A. Finkelnburg, of Winona.

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Crepicephalus unca Walcott.. 217

FIG. 1. (× 1.5.) Cranidium and side outline. U. S. National Museum, Catalogue No. 61709.

1*a*. (Natural size.) The same cranidium as fig. 1.

1*b*. (× 2.) Slightly distorted free cheek with outline restored from an associated specimen. U. S. National Museum, Catalogue No. 61710.

1*c*. (× 1.5.) Fragment of a cranidium to illustrate palpebral lobe and postero-lateral limb. U. S. National Museum, Catalogue No. 61711.

1*d*. (× 1.5.) Dorsal and side views of pygidium associated in same layer of sandstone with fig. 1. U. S. National Museum, Catalogue No. 61712.

1*e*. (× 2.) A smaller pygidium, showing doublure and a slightly different outline from that of fig. 1*d*. U. S. National Museum, Catalogue No. 61713.

The specimens represented by figs. 1, 1*a-e* are from locality **79c**, Upper Cambrian: Eau Claire formation; Willow River, near Hudson, Wisconsin. (Collected by Mr. W. A. Finkelnburg, of Winona, Minnesota.)

Saratogia volux Walcott 198

FIGS. 2, 2*a*. (× 3.) Cranidium and side outline. U. S. National Museum, Catalogue No. 61714.

From locality **78a**, Upper Cambrian: Eau Claire formation; near Eau Claire, Wisconsin.

Saratogia hera Walcott.. 197

FIGS. 3, 3*a*. (× 1.5.) Dorsal and side views of cranidium. U. S. National Museum, Catalogue No. 61715.

3*b*. (Natural size.) Spine bearing thoracic segment associated with this species. U. S. National Museum, Catalogue No. 61716.

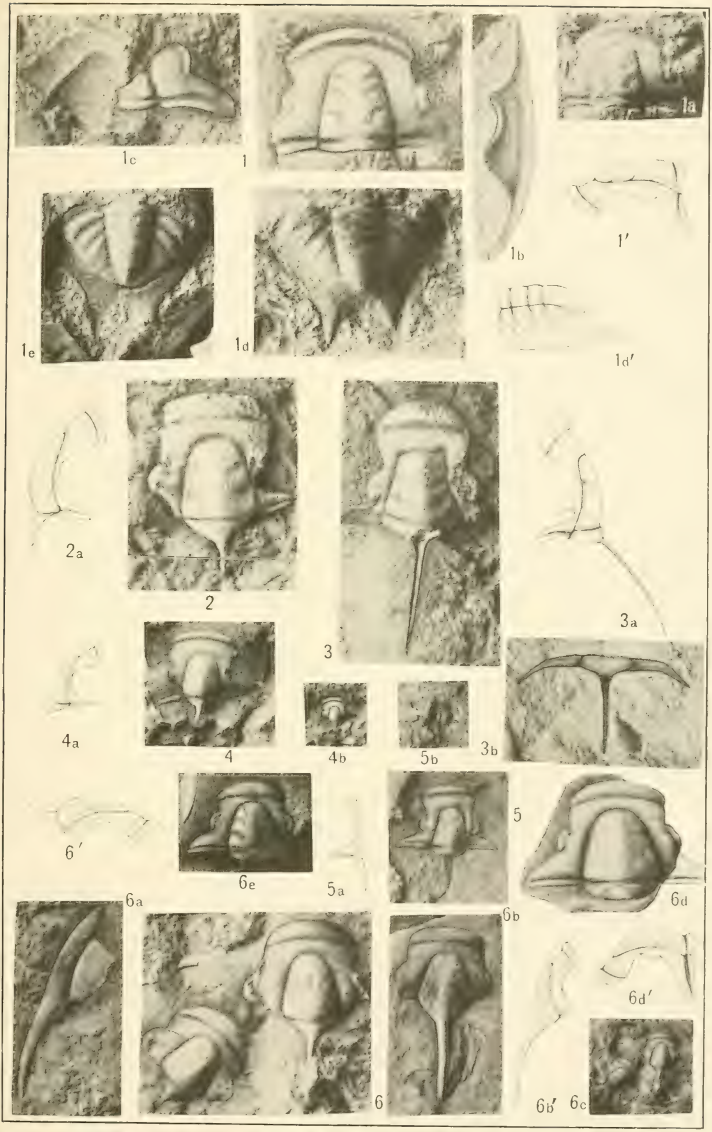
The specimens represented by figs. 3, 3*a-b* are from locality **98a**, Upper Cambrian: Franconia formation, Marine Mills, Minnesota.

Saratogia arses Walcott.. 196

FIGS. 4, 4*a*. (× 3.) Cranidium and side outline of type specimen. U. S. National Museum, Catalogue No. 61717.

4*b*. (Natural size.) The same cranidium as that represented by fig. 4.

The specimen represented by figs. 4, 4*a-b* is from locality **173**, Upper Cambrian: Nolichucky shale; Maryville, Blount County, Tennessee.



CAMBRIAN TRILOBITES

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Saratogia aruno Walcott.. 196

FIGS. 5, 5*a*. (× 4.) Cranidium with cast of occipital spine. U. S. National Museum, Catalogue No. 61718.

5*b*. (Natural size.) The same cranidium as that represented by fig. 5.

The specimen represented by figs. 5, 5*a-b* is from locality 128, Upper Cambrian: Conasauga formation; 1.5 miles southwest of Cleveland, Bradley County, Tennessee.

Lonchocephalus appalachia Walcott.................................. 190

FIGS. 6, 6′. (× 3.) Two cranidia with side outline (6′) of specimen on left side. U. S. National Museum, Catalogue No. 61719.

6*a*. (Natural size.) Free cheek associated in same layer with the specimen represented by fig. 6. U. S. National Museum, Catalogue No. 61720.

6*b*, 6*b*′. (Natural size.) Cranidium and side outline of a specimen with a long occipital spine. U. S. National Museum, Catalogue No. 61721.

6*c*. (Natural size.) The same specimen as that represented by fig. 6.

6*d*, 6*d*′. (× 1.5.) Cranidium and side profile of a specimen with the occipital spine broken off. U. S. National Museum, Catalogue No. 61722.

6*e*. (Natural size.) The same specimen as that represented by fig. 6*d*.

The specimen represented by fig. 6*b* is from locality **139a**, Upper Cambrian: Conasauga formation; bluish limestones in shales on road near Wades Gap, near Chepultepec, Jefferson County, Alabama.

The specimens represented by figs. 6, 6*a*, 6*c-e*, are from locality **123a**, Upper Cambrian: Maryville limestone; Big Creek, 4 miles northeast of Rogersville, Hawkins County, Tennessee.

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Lonchocephalus sospita Walcott.................................... 195

FIG. 1. (× 3.) Fragment of sandstone with several cranidia in it. U. S. National Museum, Catalogue No. 61723.

1*a*. (× 3.) Side outline of cranidium.

The specimens represented by figs. 1 and 1*a* are from locality 339k, Upper Cambrian: Eau Claire formation, near Winona, Minnesota. (Collected by W. A. Finkelnburg, of Winona.)

Hanburia gloriosa Walcott.................................... 226

FIG. 2. (× 3.) Entire dorsal shield flattened in shale. U. S. National Museum, Catalogue No. 61724.

3. (× 3.) Entire dorsal shield flattened in shale. U. S. National Museum, Catalogue No. 61725.

The specimens represented by figs. 2 and 3 are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile northeast of Burgess Pass, above Field, British Columbia.

Vanuxemella contractor Walcott.................................... 221

FIG. 4. (× 2.5.) A crushed dorsal shield, showing the principal characters of the species. U. S. National Museum, Catalogue No. 61726.

4*a*. (× 2.5.) A crushed dorsal shield varying slightly from that represented by fig. 4. U. S. National Museum, Catalogue No. 61727.

The specimens represented by figs. 4 and 4*a* are from locality 5j, Lower Cambrian: about 6 miles west-northwest of Scapegoat Mountain, Powell County, Montana.

Vanuxemella nortia Walcott.................................... 222

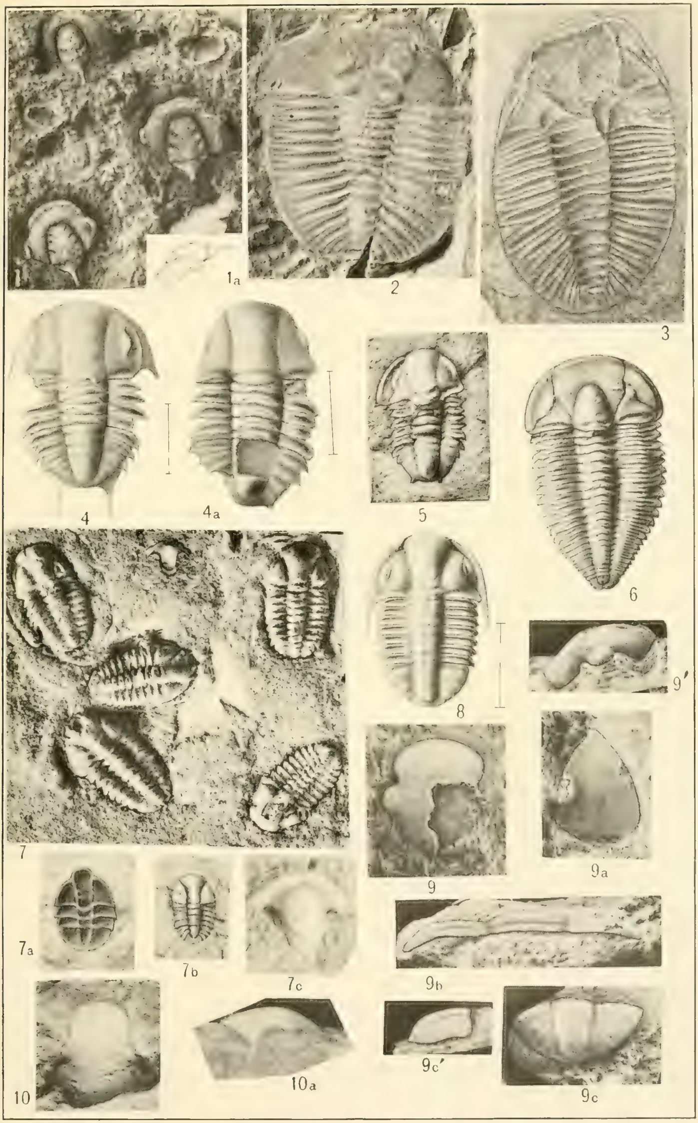
FIG. 5. (× 2.) A nearly entire dorsal shield somewhat crushed in the shale. U. S. National Museum, Catalogue No. 61728.

From locality 35c, Lower Cambrian: Mount White formation; in drift bowlder on the south slope of Mount Bosworth, British Columbia, Canada.

Agraulos stator Walcott.................................... 173

FIG. 6. (Natural size.) A nearly perfect dorsal shield that well illustrates the characters of the species. U. S. National Museum, Catalogue No. 61729.

From locality 35c, Lower Cambrian: Mount White formation; in drift bowlder on the south slope of Mount Bosworth, British Columbia, Canada.



CAMBRIAN TRILOBITES

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Karlia minor Walcott.. 224

FIG. 7. (× 4.) Group of specimens on a fragment of shale, and showing characteristics of the species. U. S. National Museum, Catalogue No. 26703.

7*a*. (× 10.) A young individual with two segments. U. S. National Museum, Catalogue No. 26703.

7*b*. (× 6.) Dorsal shield with three segments. U. S. National Museum, Catalogue No. 61730.

7*c*. (× 6.) Hypostoma. A smaller hypostoma is shown on fig. 7. U. S. National Museum, Catalogue No. 26703.

The specimens represented by figs. 7, 7*a-c* are from locality 1, Middle Cambrian: Manuels River, above Conception Bay, near Topsail Head, Newfoundland.

Karlia stephenensis Walcott.. 224

FIG. 8. (× 2.) Nearly entire dorsal shield with the free cheeks restored from other specimens. U. S. National Museum, Catalogue No. 61731.

From locality 14s, Middle Cambrian: Stephen formation; Mount Stephen, British Columbia, Canada.

Tsinania cleora Walcott.. 227

FIGS. 9, 9′. (× 3.) Top and side view of cranidium. U. S. National Museum, Catalogue No. 61732.

9*a*. (× 2.) Associated free cheek. U. S. National Museum, Catalogue No. 61733.

9*b*. (× 2.) Associated thoracic segment. U. S. National Museum, Catalogue No. 61734.

9*c*, 9*c*′. (× 2.) Top and side view of an associated pygidium. U. S. National Museum, Catalogue No. 61735.

The specimens represented by figs. 9, 9*a-c* are from locality 30w, Upper Cambrian: Notch Peak limestone; House Range, Utah.

Tsinania elongata Walcott.. 228

FIGS. 10, 10*a*. (× 4.) Top and side view of a cranidium. U. S. National Museum, Catalogue No. 61736.

The specimen represented by figs. 10 and 10*a* is from locality 346e, Upper Cambrian: 2 miles west of Donald Station, on the Canadian Pacific Railway, British Columbia, Canada.

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Block of sandstone with *Lonchocephalus chippewaensis* and several other species characteristic of the Eau Claire formation of Wisconsin...... 190

A. *Hyolithes primordialis* Hall.

B. *Anomocarella onusta* (Whitfield).

C. *Pagodia thea* Walcott.

D. *Lonchocephalus chippewanesis* Owen (p. 190, and see pl. 34).

E. *Menomonia calymenoides* (Whitfield) (p. 162).

F. *Crepicephalus iowensis* (Owen) (p. 207).

G. *Dicellomus politus* Hall.

H. *Obolus matinalis* Hall.

U. S. National Museum, Catalogue No. 61737.

From locality 83a, Upper Cambrian: Eau Claire formation; Rock Falls, Dunn County, Wisconsin.

LONCHOCEPHALUS CHIPPEWAENSIS Owen (D) AND OTHER SPECIES

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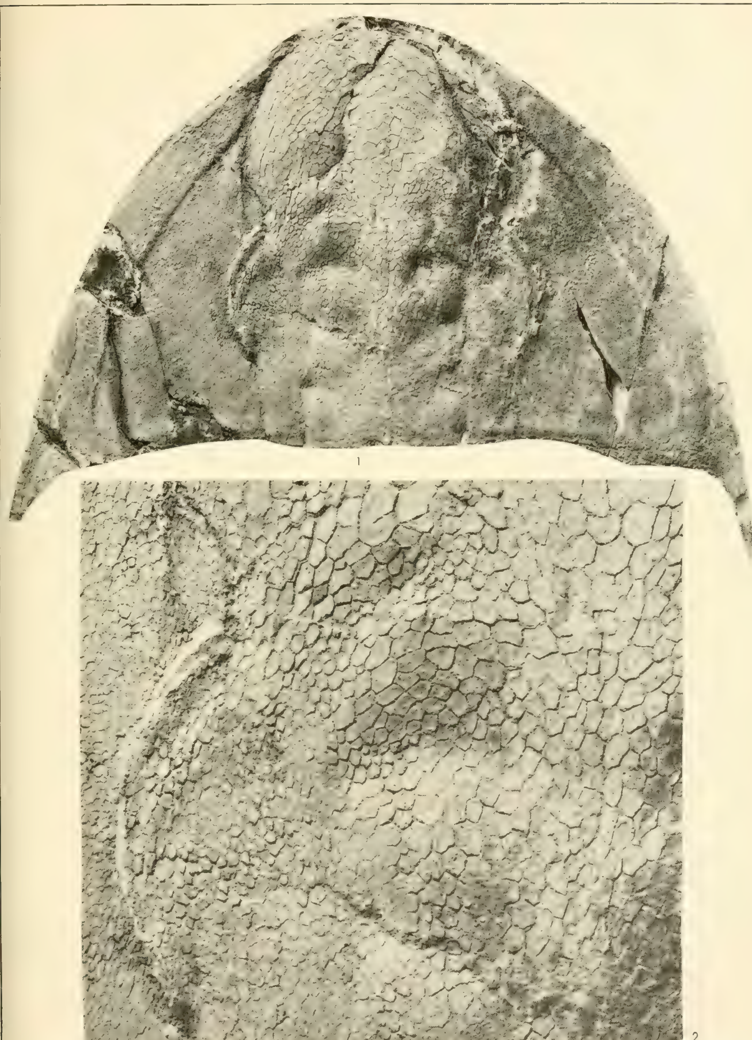
Wanneria walcottana (Wanner) 219

FIG. 1. (Reduced to three-fourths natural size.) Cranidium crushed nearly flat in argillaceous shaly rock.

2. (× 2.5.) Portion of the surface of the specimen represented by fig. 1, enlarged so as to bring out the reticulate structure.

The specimen represented by figs. 1 and 2 is from (12x) Lower Cambrian: 1 mile (1.6 km.) north of Rohrerstown, Lancaster County, Pennsylvania. It was loaned to me by Dr. H. Justin Roddy.



WANNERIA WALCOTTANUS (Wanner)

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 6 NUMBER 4

CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 4.—RELATIONS BETWEEN THE CAMBRIAN AND PRE-CAMBRIAN FORMATIONS IN THE VICINITY OF HELENA, MONTANA

(With Plates 39 to 44)

BY
CHARLES D. WALCOTT

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No. 4.—RELATIONS BETWEEN THE CAMBRIAN AND PRE-CAMBRIAN FORMATIONS IN THE VICINITY OF HELENA, MONTANA

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INTRODUCTION

In a recent memoir[1] on the fauna of the Belt formation near Helena, Montana, Dr. August Rothpletz states that he found Lower Cambrian fossils in a shale above a limestone which he identified as the typical Helena limestone of the Belt series,[2] and beneath another limestone regarded by him as also a part of the Helena limestone. He also states that in his four days' work about Helena he failed to find any evidence of an unconformity at the base of the Cambrian and therefore concludes that the Helena limestone and associated formations of the Belt series are of Cambrian age and not pre-Cambrian.

Since my own extended examinations as well as those of other geologists and paleontologists as to the position of the Helena limestone and the age of the fossil fauna of the region lead to conclusions very different from those of Doctor Rothpletz, it has seemed to me

[1] Die Fauna der Beltformation bei Helena in Montana. Munich, 1915, pp. 1-46, with 3 plates.

[2] Bull. Geol. Soc. America, Vol. 10, 1899, Pre-Cambrian Fossiliferous Formations, by Charles D. Walcott, pp. 210-213.

advisable to review in the present paper authentic data on the relations between the Cambrian and pre-Cambrian formations in the vicinity of Helena.

As the conclusions of Rothpletz are based primarily on the finding of Cambrian fossils in a shale interbedded in what he decided to be the "Helena" limestone, the first point to determine is the stratigraphic position of the limestone called "Helena" in his section of the formations on the eastern side of Mount Helena. If the limestone he identified as the "Helena" is not the Helena, then the elaborate deductions and conclusions he has drawn therefrom are without foundation.

In order that we may more clearly understand the distribution of the several formations about the city of Helena, a part of the geological map accompanying Bulletin 527 of the U. S. Geological Survey[1] is reproduced in outline as plate 39 of the present paper. It should be mentioned that at the time Dr. Rothpletz made his study of the rocks in that vicinity he had with him neither a topographic nor geologic map, and apparently before publishing his memoir he had not seen Bulletin 527 of the U. S. Geological Survey[1] containing a fine geological map of the region and a description of the several geological formations. The only geologic map of the area that he refers to is a small scale map published by Weed[2] with all the Cambrian formations grouped under one color. He was therefore dependent on his limited observations for the identification of the pre-Cambrian, Cambrian, and later limestone formations in the Helena section.

Rothpletz speaks of the old and very poor topographic map that he was obliged to refer to when writing his memoir. This is the same map that was used by me when making examinations about Helena in 1898, and it was on this account that the Walcott section was so broadly generalized, and the exact locality of the section and of the figures 3 and 4 so indefinitely stated (see p. 262).

When I made my examinations of the formations near Helena, Mr. L. S. Griswold was engaged in preparing a geologic map under the direction of Mr. Weed, and in studying the Cambrian and later formations more or less in detail. In view of that work, and anticipating the early publication of the results, I did not study and measure the Cambrian and superjacent formations in detail and only collected

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[1] Ore Deposits of the Helena Mining Region, Montana. By Adolph Knopf, 1913.

[2] Professional Paper 74, U. S. Geol. Survey, 1912, pl. 1.

a few fragments of fossils from the Meagher limestone and Park shale of the Cambrian, my objective being largely to discover the relations existing between the basal formation of the Cambrian [Flathead quartzite] and the pre-Cambrian formations. The Helena limestone was examined north, west, and east of Mount Helena and its thickness was roughly measured on the line of my diagrammatic section southeast of the suburb of Lenox.

WALCOTT DIAGRAMMATIC SECTION OF 1899[1]

The diagrammatic section showing the relations between the Cambrian and Belt terranes, to which Rothpletz refers a number of times, began on the east with the section of the Belt Mountains in the vicinity of White's Canyon, thence passing over the Lake Beds of the Missouri River Valley to the eastern base of Spokane Hills, north of the boundary line between Lewis and Clark and Jefferson counties. Passing over the Spokane Hills, it next extends across the Lake Beds of the broad Prickly Pear Creek Valley about a mile and a half (2.4 km.) north of the boundary line between Lewis and Clark and Jefferson counties, and a little north of East Helena, where it bends to the west-southwest, near its crossing of the Northern Pacific and Great Northern Railway tracks; this was in order to avoid striking into the fault line (*B-B*) about a mile east of Lenox. Southwest of the railway tracks the section passes over an area underlain by the Empire shale (*Ae*),[2] and reaches the Helena limestone (*Ah*) in the foothills about 1.25 miles (2 km.) southeast of the suburb of Lenox, or about 2 miles (3.2 km.) from the thickly settled suburb in the southeastern portion of the city of Helena. In the diagrammatic section (fig. 10) the Helena limestone is represented as being overlain by formations that include Cambrian, Devonian, and Carboniferous strata. No attempt is made to represent the character of the Cambrian in the sketch other than by a strong black line and lines above it, since the point desired to be brought out in the section and the text was the thinning out of the Helena limestone (*Ah*) and Empire shale (*Ae*) both from the east and west toward the Spokane Hills, and that a great unconformity was indicated by the fact that the Cambrian rested on the Spokane shales in the Spokane Hills with the Helena limestone and Empire shale absent, and that in the Belt Mountains as well as in the vicinity of Helena both of those formations were present between the Spokane shales and the Cambrian.

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[1] Bull. Geol. Soc. America, Vol. 10, p. 211.

[2] The lettering used is the same as that on the map (pl. 39).

Reproduction in black and white of portion of geological map of Helena and vicinity published, in colors, as plate 7, Bulletin 527, U. S. Geological Survey. Lettering of geological formations explained in legend on original map.
Fault lines.—There are four (4) principal fault lines. The two most easterly, *A-A*, *B-B*, have displaced a large block of strata that has moved to the northeast. The middle fault, *C-C*, has made little horizontal change in the position of the formations. The westerly fault (O-O), Oro Fino Gulch fault, cuts through the formations on the eastern lower slope of Mount Helena with a relatively small horizontal displacement of the Cambrian and pre-Cambrian formations.
Walcott section.—The approximate line of the diagrammatic section (fig. 10, p. 263) is indicated on the map by the broken line *W-W*.

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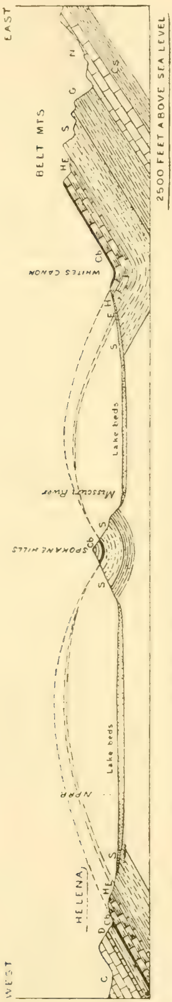

FIG. 10.—Big Belt Mountains—Helena section, indicating unconformity between the Cambrian and pre-Cambrian. Diagrammatic section showing relations between Cambrian and Belt terrane.

Rothpletz states that he could not find the localities of Walcott's diagrammatic figures 3 and 4 showing the unconformity between the Cambrian and pre-Cambrian southeast of Helena. I find on looking up my field notes of September 30, 1898, that I crossed from the west side to the east side of the city of Helena, and followed the outcrop of the Flathead quartzite to the southeast and noted that a half mile east of the thickly settled southern section of the city the Helena limestone is not more than 20 feet below the base of the Flathead quartzite, the interval being filled by arenaceous and argillaceous shales, and that in a prospector's cut about one mile southeast of the suburb of Lenox, the quartzite rests directly on the limestone. At this line of contact there is a slight unconformity between the limestone and quartzite that in a distance of 10 feet shows the upper surface of the limestone eroded so as to cut out 18 inches in thickness of the upper layer. A pen and ink sketch was made in the notes and from it the diagrammatic figure 3 was drawn (see fig. 12, p. 286). This particular locality is about 1.25 miles southeast of the suburb of Lenox, near line of section *W-W*, plate 39.

The field notes state further that at another prospect cut about a mile to the southeast of the one above mentioned a band of argillaceous shale rests on the Helena limestone and the Flathead quartzite rests on the shale. The only evidence of non-conformity here was a small mass of shale left by erosion above the general level of the summit of the shale and rising into the basal bed of the Flathead quartzite. A sketch accompanied this note and from it the diagrammatic figure 4 was drawn (see fig. 13, p. 286). It is quite probable that in the interval between my visit in 1898 and that of Rothpletz in 1913, the sides of the two cuts may have broken down by weathering and thus the contact with the basal bed of the Flathead quartzite have been covered over, or it may be that Rothpletz either did not find the particular localities or that in his confused identification of the pre-Cambrian Helena limestone he did not know which limestone he was on. These localities are southeast of the fault *B-B*, plate 39.

The notes further state that such small unconformities are repeated on a larger scale along the strike by the increase in the thickness of the shales, or by their removal by pre-Cambrian erosion in various places, so that the Flathead quartzite rests in some localities directly on the limestone and in others on the shale.

This latter statement was based on observations made along the line of contact of the Cambrian Flathead quartzite and the pre-Cambrian rocks, from about 1.25 miles (2 km.) southeast of the

suburb of Lenox for 2.5 miles (4 km.) to where both formations are cut off by a mass of rhyolite breccia about a mile (1.6 km.) north of the old mining railroad station of Montana City.

We will now consider the Algonkian and Cambrian formations as they were known in the vicinity of Helena, by publication in 1913, also a section of the Cambrian formations 20 miles (32 km.) northeast of Helena and in the Little Belt and Big Snowy Mountains, in order that we may better understand the Mount Helena section and the Rothpletz interpretation of it.

ALGONKIAN AND CAMBRIAN SECTIONS AT HELENA AND VICINITY

In Bulletin 527 of the U. S. Geological Survey,[1] Dr. Adolph Knopf publishes a description of the sedimentary series at Helena, the data for which are taken largely from an unpublished report by Mr. Walter Harvey Weed.[2]

PRE-CAMBRIAN ALGONKIAN FORMATIONS

In speaking of the pre-Cambrian Algonkian formations Knopf says:[3]

> In the Helena district only the four uppermost formations are found, and the top of the Marsh shales has been eroded before the deposition of the Cambrian, so that the upper limit of the formation and its entire thickness are not known.

The four formations mentioned are as follows, from below upward:

Spokane shale.—(*As* on map.) It consists of massive- and thinly-bedded, siliceous shales, usually of a deep-red color, but passing in places into green and gray rocks, containing arenaceous beds merging into sandstone. The rocks form low hills, bordering the Prickly Pear Valley to the northwest of Helena, and a small outcrop occurs between East Helena and Helena between the railway tracks and Prickly Pear Creek.

Empire shale.—(*Ae* on map.) The Empire shale is a shale composed of massive-bedded, greenish-gray, well-banded, siliceous shales, showing color bandings of light and dark material and locally a marked knotty structure.

These shales underlie a considerable area of North Helena and the subdivision known as Kenwood, and extend around to the north

[1] Ore Deposits of the Helena Mining Region, Montana. Knopf, 1913, pp. 86-94.

[2] Idem, p. 86. [3] Idem, p. 87.

and westward of Mount Helena for several miles. Near the railroad about 2 miles (3.2 km.) west of East Helena they consist of pale, greenish-gray slates with characteristic purple spots.

Helena limestone.—(*Ah* on map.) "The Helena limestone is a formation composed predominantly of impure bluish-gray or gray non-crystalline limestone. The limestones occur in beds 1 foot to 6 feet thick and contain thin, interbedded bands of gray siliceous shale, more rarely of green to purple clay shales. The limestones are ordinarily dark blue on fresh fracture, but show a characteristic buff-colored, velvety appearing surface on weathering. The upper beds have a rough surface, with a pale or blue-gray color, and resemble Cambrian rocks. These beds alternate with shale and form the ridges on the northwest foot slopes of Mount Helena.

"The formation has no distinctive physiographic expression within the district, but its relatively massive bedding gives the limestone prominence on the slopes about the city.

"The name was given the formation by Walcott from its typical occurrence about the city of Helena.

"The formation is barren of fossils, though the oolitic character and the local presence of carbonaceous markings has led to the belief that they will ultimately be found. The estimated thickness of 2,400 feet in this vicinity is based on rough measurements, as it is impossible to find a satisfactory exposure of the entire formation for exact measurement. The formation covers a large part of the district, especially about the borders of the Prickly Pear Valley. So far as known the rocks are conformable to the formations above and below, and grade into them by intercalations of shale. The upper and lower limits are therefore not sharply definable. About a mile east of Helena the Marsh shale is wanting and the Cambrian quartzite rests directly on the eroded surface of the Helena limestone. Good outcrops are seen near the high school within the city limits.

"On the north face of Mount Helena the Cambrian quartzite rests on dark-blue and dense limestones, weathering buff, and these rocks in turn rest on pink and buff-colored shales, which appear red in most exposures and are included as part of the Helena limestone. These reddish shales contain numerous massive beds of white cherty limestone, forming reefs running obliquely across the slopes and extending downward within a few yards of the streets of Kenwood. The beds of limestone are 6 to 10 feet thick and in weathering and character resemble those of Paleozoic rocks. The same pink and buff-colored shales, with interbedded limestones, are seen in the

gulch east of Lenox, the 4,350-foot knoll [on topographic map] at that locality showing light-gray, fine oolitic limestone with black grains in a white matrix."[1]

Marsh shale.—(*Am* on map.) The Marsh shale consists of red and yellowish-green shales and thin-bedded sandstones.

CAMBRIAN FORMATIONS

These formations were studied by Weed on Mount Helena and they compare quite closely with the same formations as published by Weed in 1900 in his account of the Geology of the Little Belt Mountains of Montana[2] (see p. 273).

From the base upward the following is the order of succession at Mount Helena[3]:

Flathead quartzite.[4]—(*Єf* on map.) "The Flathead quartzite, the lowest formation of the Cambrian system, consists of a hard, fine-grained, massive quartzite varying to grayish-yellow gray sandstone. The lowest stratum in places is pebbly, grading into a conglomerate at the base. The bedding planes range from a few inches to a few feet apart and faint lines of sedimentation are seen. The rock is jointed by sharply cut planes. Higher up in the formation thin bands of gray-brown mottled and green micaceous shale are found locally, increasing in thickness toward the top. The pebbles in the basal bed vary in character from place to place and consist predominantly of the material derived from the immediately underlying beds. As mentioned elsewhere, this quartzite is in most places apparently conformable to the Algonkian, but there is a slight angular unconformity observable east of Helena, and the Marsh shale is in places cut out, so that the quartzite rests directly upon the Helena limestone. The only fossils recognized are scolithus borings. The total thickness of the Flathead quartzite in the Helena district is 300 feet. The formation is easily recognized in the topography of the area, as the resistant nature of the beds causes them to form low foothill ridges, which are prominent on the slopes of Mount Helena, and as the cap reef on the mountain ridge running southward from that peak." (Evidently westward as the Flathead does not extend southward from the peak and the ridge extends west-southwest.)

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[1] Bull. 527, U. S. Geol. Surv., pp. 88-89.
[2] Twentieth Ann. Rep., U. S. Geol. Surv., Pt. 3, pp. 284-287.
[3] Knopf, Bull. 527, U. S. Geol. Surv., 1913, pp. 89-90.
[4] Idem.

Wolsey shale.—The Wolsey shale, Meagher limestone, Park shale, Pilgrim limestone, Dry Creek shale, and Yogo limestone are all included under *Ꞓls* on the map. "The Wolsey shale[1] consists of micaceous and calcareous gray to greenish shales, which contain small oval and flat concretions of limestone, grading in places into thin and very irregular plates of limestone. Trilobite and shell remains of Cambrian types occur abundantly along the contact between these shales and limestones. The rocks are in few places well exposed, owing to their soft and crumbly nature, but their position is recognizable by the ravines cut in them or, on the mountain slopes, by their forming a more gentle angle between the limestone bluffs above and the quartzite ridges below. They have a thickness of about 420 feet" (in the Helena district).

"*Meagher limestone.*[1]—The Meagher limestone is composed of light-gray to bluish limestones, which are shaly near the base, but grade into alternating beds of massive, dark-colored and flaggy, white limestones, and these into thinly-bedded, dark-purple to blue, fossiliferous limestones, forming the top of the series. In other regions the rocks are pebbly, but this character is not conspicuous in the Helena district. The rocks have an estimated thickness of 400 feet. They form the characteristic bluffs on the north face of Mount Helena, extending from the gentle slopes formed by the Wolsey shale upward almost to the very summit of the mountain. The rocks are also seen in the bold cliffs below the east side reservoir. Fossil remains occur, but no collections were made.

"*Park shale.*[2]—The Park shale consists of earthy and micaceous dark-gray to green or purple shales. The rocks are not well indurated and crumble readily, so that very few good exposures are seen. A partial section is exposed in the quarry near the upper part of the city of Helena, and shows the formation to contain lavender or pinkish beds, grading through green shales to a grayish earthy shale carrying an abundance of small fossil shells, identified as *Obolella* [*Obolella* (*Westonia*) *ella*].[3] The upper portion contains limestone lenses in a jaspery shale, which grades downward into a dense cherty rock resembling hornstone. This shale has an estimated thickness of 150 feet. It forms the flat bench on the summit of Mount Helena, between the apex and the northern cliffs, and covers the ridge followed by the trail.

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[1] Bull. 527, U. S. Geol. Surv., p. 90.

[2] Idem, pp. 90-91.

[3] The reference now is to *Obolus* (*Westonia*) *ella*. (Monogr. 51, U. S. Geol. Surv., 1912, p. 455.)

"*Pilgrim limestone.*[1]—The Pilgrim limestone consists of massive beds of bluish to dark-gray limestones. The lowest bed is a dark-colored crystalline rock, mottled with yellow and dark-gray spots; its peculiar coloration and massive character are characteristic of the limestone throughout Montana. This bed of mottled limestone is overlain by light-gray to white, non-crystalline limestone, used for making quicklime in the Grizzly Gulch kilns. No fossils have been found in the mottled limestone, but its position and lithologic character correlate it with the 'Mottled' limestone of the Yellowstone Park folio. This formation occurs on the very summit of Mount Helena, where it forms the uppermost bed of the gentle syncline sweeping down the southeastern side of the mountain. It is also seen in bluffs above the East Side reservoir, and forms a low cliff extending up Oro Fino Gulch for 2 miles above the city, the relief being due to the crumbly nature of the Park shale in which the gulch is being eroded. The mottled beds are 150 feet thick and are overlain by white limestone, which is included in the formation. The total thickness of the formation is 317 feet.

"*Dry Creek shale.*[1]—The Dry Creek shale consists of light-colored brownish-yellow, red, and pink shales and calcareous sandstones. The formation is well exposed in few places, but can be recognized by its topographic relief, as it forms sags in the high ridges and ravines on the mountain flanks. No fossils have been found in the shale. It is correlated on the basis of lithology and stratigraphic position with the Dry Creek shale of the Threeforks and Little Belt regions. The thickness is estimated at 40 feet.

"*Yogo limestone.*[1]—The Yogo limestone consists of light-colored, thin-bedded limestones, with crinkly bands and films of jasper, in many places composed of limestone pebbles held in a glauconitic matrix. The formation corresponds to the so-called 'Pebbly' limestone of the Threeforks folio. It has a thickness of 175 to 450 feet. The jaspery, flaggy limestone forms prominent buttress exposures along the east side of Oro Fino Gulch above the city."

SUMMIT OF THE CAMBRIAN

On the map accompanying Bulletin 527 the line between the Cambrian and Devonian rocks was supposed to be at the upper limit of a well-marked shale deposit. Later work, however, after the map was made, showed that the limestones above this shale also belonged to the Cambrian, and that all of the south and southwest slope of

[1] Bull. 527, U. S. Geol. Surv., p. 91.

Mount Helena was formed of Cambrian rocks; also that the upper boundary of the Cambrian southwest, south, and southeast of Helena would have to be placed at a higher horizon. This, however, does not affect the map for the purpose of the present paper.

CAMBRIAN SECTION 15 TO 20 MILES NORTHEAST OF HELENA, MONTANA, ALONG BEAVER CREEK, ON THE EAST SIDE OF THE MISSOURI RIVER

Beaver Creek rises on the slopes of the north end of the Big Belt Mountains and flows westward to where it empties into the Missouri River. The formations are finely exposed along this canyon. Beneath the Flathead quartzite is a considerable thickness of siliceous, slaty, dark shales of the Grayson formation of the Belt terrane that strike north 42° west (magnetic), and dip 30° southwest 48° west. These shales are overlain by the basal beds of the Flathead quartzite which strike north 58° west (magnetic), dip 30° south 32° west. This dip increases to 40° and gradually to 75° near the top of the ridge on the north, and then returns to 35°. The strike at the top of the ridge is north 50° west (magnetic). The section is given in my field notes as from the bottom up as follows:

ALGONKIAN

Siliceous, slaty, dark shales of the Grayson formation, Belt terrane.

CAMBRIAN

FLATHEAD SANDSTONE

Gray, massive-bedded, quartzitic sandstone, with a few conglomerate layers formed of small quartz pebbles.

At 225 feet from base thinner-bedded quartz sandstones occur and again at 355 feet a band of thinner beds comes in. At 640 feet the massive beds of quartz sandstone give way to shaly sands and shales ....640 feet.

WOLSEY SHALES

Thin-bedded and sandy shales with irregular, thin-bedded, shaly limestone carrying Middle Cambrian fossils at 180-200 feet. Purple and green argillaceous shales appear at about 600 feet from the base ....695 feet.

Intrusive layers of eruptive rock occur from above 100 feet at various horizons as interstratified thin sheets that add about 120-150 feet to the total thickness. Fragments of shales are included in the eruptive layers on the north side of Beaver Creek where the eruptive follows the parting of the shale on the lines of bedding for long distances; in places it cuts across the beds and drops a few feet to another parting or disappears altogether.

MEAGHER LIMESTONE

Thin-bedded, bluish-gray limestone with fossils at base. Strike north 50° west. Dip 30° southwest............................6 feet.

Ptychoparia
Acrotreta
Iphidea

Eruptive ....11 feet.

Limestone. At 165 feet from its base the limestone becomes more massive and gray in color, and is made up of thin layers grouped in massive layers. At 360 feet thicker individual layers appear and continue to the top of the formation. Fragments of trilobites show here and there but very rarely.

Total ....720 feet.

A bed of irregularly-bedded, eruptive rock rests on the limestone beneath the Park shales.

PARK SHALES

Green and purple argillaceous shale........................290 feet.

PILGRIM LIMESTONE

(*a*) Massive-bedded, gray, oolitic limestone, passing above to bluish-gray, thin-bedded, fossiliferous limestone...............205 feet.

Fragments of Cambrian fossils were seen in a few layers.

(*b*) Light-gray, arenaceous, finely granular or subcrystalline limestone. (Strike north 40° west. Dip 23° southwest.)

In the lower 25 feet small *Hyolithes* occur with bits of trilobites. Above, the strata become more massive and coarser...........135 feet.

A bed of intrusive lava 3 feet thick occurs near the base of (*b*).

The Dry Creek shale and Yogo limestone of Weed were not recognized in this section. The shale is usually only a thin bed that is readily concealed by débris from the limestones above.

SUMMARY:

Pilgrim limestone	340	feet.
Park shale	290	"
Meagher limestone	720	"
Wolsey shale	695	"
Flathead sandstones	640	"
Total Cambrian	2,685	feet.

The next overlying limestone is referred to the Devonian. No line of unconformity was noted in the ridge where the section was measured, although there is undoubtedly an unconformity by non-deposition of the Ordovician and Silurian.

DEVONIAN

1*a*. Massive-bedded, dark steel-gray, arenaceous limestone, weathering to a dirty brownish-gray (oil-stain brown) color.

Obscure fragments of fossils occur at the base. At 65 feet a band 18 inches thick in a massive layer 3 feet thick is almost made up of *Stromatopora*, *Favosites*, etc.

Obscure fragments of gastropods and brachiopods occur 162 feet up and again at 350 feet up in a thin layer of light-gray, fine arenaceous limestone and a dark layer above....................575 feet.

Noted: *Stromatopora, Streptelasma, Heliolites.*

Sections of brachiopods and a gastropod.

1b. Light-gray, arenaceous limestone that forms a strongly marked, even-topped, low cliff, towards the summit. Strike north 60° west (magnetic). Dip 23° southwest......................180 feet.

Numerous small, cherty nodules occur in association with bits of silicified *Stromatopora,* with thinner layers near the top.

This limestone is succeeded by limestones referred to the Carboniferous.

CARBONIFEROUS

1a. Bluish-gray, thin-bedded limestones with cherty nodules and layers of chert in some of the layers. (Layers 1-6 in., 12 in., 24 in., thick.)

This band begins at a saddle west of the slope on the top of *1c,* and is a marked feature on the north side of Beaver Creek beneath the massive, gray, conglomerate limestone cliffs. Total of *1a*..780 feet.

At 375-400 feet noted fossils, and at 740 feet from the base a fauna, in which the following species have been identified by Dr. George H. Girty of the United States Geological Survey:[1]

Chonetes loganensis
Productus ovatus
Productus semireticulatus
Productus gallatinensis
Pustula scabricula
Camarotoechia metallica
Spirifer centronatus
Bellerophon sp.

1b. Light-gray arenaceous to almost pure granular limestone in massive beds. In places carries cherty nodules. Weathers rough, forming jagged cliffs.

At 1,225 feet from the base of *1b* corals occur and at 1,850-1,900 feet up the corals are in great abundance.

Masses of Diphophyllum 2 to 3 feet in diameter.

Syringopora, etc., etc.

Total of *1b*..2,075 feet.

1c. Shaly sands with interbedded bands of gray limestone and sandstone.

At about 600 feet up remains of Bryozoa are abundant. The section is here broken by the canyon of the Missouri River. On the west side of the river high cliffs of sandstone, etc., rise fully 1,000 feet back from and above the river.

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[1] "I would unhesitatingly call this fauna Carboniferous and also unhesitatingly call it Mississippian. It appears to represent the horizon of the Madison limestone. It is not, however, the most typical phase of the Madison fauna, which is of early Mississippian age, and I would not state positively at this time that it might not belong in the middle Mississippian. Even so, it would be within the limits of the Madison limestone as they are at present recognized." (Information in letter from Dr. Girty, of April 5, 1916.)

CAMBRIAN SECTION OF THE LITTLE BELT MOUNTAINS

Dr. Walter H. Weed has published a description of the Cambrian rocks of the Little Belt Mountains section 60 to 70 miles east of Helena and 30 to 40 miles east of the Big Belt Mountains.[1] The several formations were here first named as follows:

7. Yogo limestone	130 feet.
6. Dry Creek shale	40 "
5. Pilgrim limestone	97 "
4. Park shale	800 "
3. Meagher limestone	100+ "
2. Wolsey shale	150 "
1. Flathead sandstone	160 "

Unconformity.

Belt series: Spokane shale.

A brief description is given of each formation and a plate (pl. 40) of comparative columnar sections of Middle Cambrian formations in central Montana.

Algonkian formations.—The pre-Cambrian formations exposed on Belt Creek south of Neihart are described and the statement made that the unconformity between the upper formation, the Spokane shale, and the Cambrian Flathead sandstone is well shown on Sawmill Creek.[2]

The Belt formations are named as follows:

5. Spokane shale	210 feet.
4. Grayson shale	955 "
3. Newland limestone	567 "
2. Chamberlin shale	2,078 "
1. Neihart quartzite	702 "

Unconformity.

Archean.

STRATIGRAPHIC SECTION OF PALEOZOIC FORMATIONS IN THE BIG SNOWY MOUNTAINS, MONTANA[3]

In an unpublished manuscript report by W. R. Calvert of the U. S. Geological Survey, on the Big Snowy Mountains area 60 miles east of the Little Belt Mountains, based on work done by him and his party during the field seasons of 1907 and 1911, there is a brief account of the Cambrian and pre-Cambrian formations in the vicinity of Half

[1] Twentieth Ann. Rept., U. S. Geol. Surv., Pt. 3, 1900, pp. 284-287.

[2] Idem, p. 283.

[3] Published by permission of the Director of the U. S. Geological Survey.

Moon Pass, which is in the southern central section of the Big Snowy Mountains.

Belt series.—Of this series Calvert writes as follows: "The oldest strata exposed in the area are correlated with the upper part of the Belt series, of Algonkian age, named from the Little Belt Mountains where studied and first described by Weed.[1] In the Big Snowy Mountains these rocks were actually seen only in Half Moon Pass amphitheatre, but they are believed to be exposed also in connection with several other similar topographic features at the heads of Blake, Careless, and Timber creeks. A thickness of about 300 feet of these strata is exposed near Half Moon Pass, where they consist of dark, limy shale highly indurated and approximating a slate in physical condition. No fossils were found in these rocks, but their similarity to strata in the Little Belt Mountains of definitely determined Algonkian age, together with the marked angular discordance between them and the overlying Cambrian quartzite, seem sufficient to justify their assignment to the Belt series of the Algonkian. At only one locality was the unconformity noted, namely, just to the east of Swimming Woman Creek, in what, if surveyed, would probably be the S. E. $\frac{1}{4}$ of Sec. 9, T. 11 N., R. 19 E. *At this locality the Algonkian shale dips south at a 19° angle, whereas the overlying quartzite lies practically horizontal, so that an angular unconformity is apparent.*

"It is not known definitely whether the calcareous nature of the shale is due to original content or to later infiltration of descending waters charged with lime from the Paleozoic strata higher in the section. The latter assumption is given weight by the presence of many joint planes and a number of fault zones filled with calcite undoubtedly of secondary origin."

Cambrian formations.—"Lying unconformably on shale of the Belt series is a sandstone 75 feet thick composed mainly of pure quartz. Although indurated, the sandstone is not a quartzite, as stratification is distinct, and cleavage along bedding planes is marked. It is evidently a shore deposit, as cross-bedding is abundant and ripple marks are beautifully developed. The shore phase is also attested by abundant worm trails, the only evidence noted of life existing at the time of deposition of the sandstone. Layers of quartz conglomerate are of frequent occurrence in the sandstone with pebbles

[1] Weed, W. H., The Little Belt Mountains Folio, Geol. Atlas of the U. S., No. 56, 1899.

generally small, but occasionally attaining a diameter of one inch. Because of the lithologic character and stratigraphic relations of the sandstone, it is correlated with the Flathead quartzite of the Little Belt Mountains section.

"Immediately above the Flathead quartzite is a mass of soft strata about 750 feet thick. Continuous exposures of this portion of the stratigraphic section do not occur, but wherever observed the rocks consist mainly of fissile micaceous shale, prevailingly of a greenish hue. There are occasional intercalations of platy, calcareous layers, containing numerous greenish granules, presumably of glauconite. Three collections of fossils were obtained from these rocks in the vicinity of Half Moon Pass. The lowest fossiliferous zone occurs very near the base of the formation and from this zone *Asaphiscus capella* Walcott, *Hyolithes* sp., and *Ptychoparia* sp. were obtained. About 170 feet higher stratigraphically fossils identified as *Obolus matinalis* (Hall) were found in abundance in a calcareous layer. Still higher, fossils determined as *Asaphiscus capella* Walcott were collected. . . . .[1]

"Overlying the Wolsey shale is a formation with very distinct and characteristic lithology. It is composed of layers of firmly cemented, flat, limestone pebbles, with thin parting of gray fissile shale. The thickest layer of conglomerate noted was 4½ feet, and the general average was 2 or 3 feet. Worm trails and ripple marks are plentiful on the upper surfaces of the conglomerate layers, so it would appear that the formation represents a shore phase of marine deposition, a view strengthened by the flat character of the limestone pebbles. From the lithology and the relation to the underlying Wolsey shale this conglomerate is correlated with the Meagher limestone, described by Weed in the Little Belt Mountains folio."

Carboniferous.—"Madison limestone (Mississippian): Overlying the Meagher limestone is a thick mass of calcareous strata that constitutes the great bulk of the Big Snowy Mountains. This mass may be separated into three distinct lithologic units. The lowermost comprises 200 feet of chocolate-colored limestone, cherty throughout and massive in general appearance, though in reality somewhat thinly bedded. A striking characteristic in connection with this limestone is the strongly fetid odor emanating when struck with a hammer, due no doubt to some form of sulphur. It was supposed in the field that this limestone corresponds to one of similar character in the

[1] Names of species are as identified by Walcott.

Little Belt Mountains, assigned by Weed to the Siluro-Devonian. In the Half Moon Pass locality, however, the writer collected fossils from the limestone, near the top, to be sure, but from a zone similar in every respect to the strata between that zone and the Meagher limestone. According to Dr. Girty, who made the identifications, this collection contained *Pinnatopora* sp., *Spirifer centronatus*, and several species of *Fenestella*, referred by him to the Madison limestone of Mississippian age."

Summarized, the Big Snowy section is stated by Calvert as follows:

	Age		Formation	Character	Thickness in feet
	Unconformity.				
Paleozoic	Carboniferous	Mississippian?	Quadrant	Red and green sh., reddish ss. and usually ls. as top member	1,300
Paleozoic	Carboniferous	Mississippian	Madison ls.	Ls., 4 mass members with shaly ls. between	1,400
				Ls. thinly bedded	350
				Ls. chocolate-brown, fetid odor when struck	200
	Unconformity?				
Paleozoic	Cambrian		Meagher ls	Ls. conglomeratic, flat pebbles	300
			Wolsey sh	Mainly greenish, micaceous sh	750
			Flathead qtzt	Coarse ss. with qtz. congl. layers	75
	Unconformity.				
	Algonkian		Belt series	Dark, limy shale....(exposed)	300

One of the interesting features of the above section is the angular unconformity at the base of the Flathead quartzite. The uplift of the axis of the Big Snowy Mountains in pre-Cambrian time had begun and like similar uplifts of Algonkian strata in the Spokane Hills, west of the Big Belt Mountains, Montana, in the Llano area of Central Texas, and the Grand Canyon area, Arizona, had been cut down by erosion before the deposition of the basal beach sand and gravel by the transgressing Cambrian sea.

ROTHPLETZ SECTION OF MOUNT HELENA

In great contrast with the Mount Helena section of Weed is that of Rothpletz made as a result of a brief examination in 1913.[1] His section on the eastern slope of Mount Helena, from above downward, is as follows:[2]

6. Summit dolomite up to....................250 m. [812 ft.].
5. Gray schists [shales] up to.................. 60 " [193 "].
4. Bluish-gray limestones with oolite beds.....500 " [1,625 "].
3. Schists [shales] with limestones in alternating layers.
2. Brownish weathering quartzitic layer.
1. Green and gray argillaceous schists [shales].

Interpreting the above section he says, "When we compare this sequence of rock with Walcott's data, it thus appears that No. 4 corresponds to his *Helena* limestone, which he says outcrops in the upper limits of the city. No. 3 must then correspond to the Empire shales of Walcott, and No. 1 to the Spokane[3] schists [shales], to which No. 2 might be placed as the uppermost section."[4]

He thinks that this interpretation can hardly be correct because the schists of No. 1 have not the red color of the Spokane schists and because the thick, brown quartzitic layer is peculiar neither to the Empire nor the Spokane schists. He says, "A comparison for 2 with the Lower Cambrian Flathead quartzite would be nearer."[5]

In the above statement Rothpletz correlates No. 4 with the *Helena* limestone (*Ah* on map), and it is here that the vital mistake in all of his correlations was made, for his No. 4 limestone is the well-known

[1] Bulletin 527 ("Ore deposits of the Helena Mining Region in Montana") of the United States Geological Survey, with a detailed geological section and map of Helena and vicinity, was available for examination in six libraries in Munich in the fall of 1913, and it must have been accessible to Rothpletz on his return to Munich from the United States in 1913. It was issued in Washington May 1, 1913, and its receipt for the libraries of the Central-Bibliothek des Deutschen und Oesterreichen Alpen-Vereins, Geologisch-Paläontologische Sammlung des Staates, Königl. Bayerische Akademie der Wissenschaften, Königl. Bayerisches Oberbergamt., Petrographisches Institut der Universität, Zeitschrift für Krystallographie und Mineralogie was acknowledged by the America-Institut, August 30, 1913. It was catalogued as received by the Königl. Bayerische Akademie der Wissenschaften, Math.-Physikalische Klasse, 1913, Heft 3, p. 76[5], by which institution the Rothpletz paper was published, June, 1915.

[2] Rothpletz, p. 10.

[3] Rothpletz evidently did not at any time see an outcrop of the Spokane shale as it is exposed northeast of the railroad tracks over three miles (4.8 km.) east of the city. (See *As* on map.)

[4] Rothpletz, pp. 10-11.

[5] Idem, p. 11. This is the Cambrian Flathead quartzite which is described in the section of Mount Helena taken by Weed.

Cambrian Meagher limestone of Weed. The Helena limestone occurs *beneath* No. 1 of the Rothpletz section, and may be found, as stated by Weed, near the high school within the city limits and to the north and west in the Kenwood subdivision. It also extends southeast to and beyond the main business street of the city, ending up against the quartz monzonite (*qm* on map) mass that extends northeast and southwest across the city, cutting off the outcrops of all of the sedimentary formations (see map, pl. 39).

Reference by me to the *Helena* limestone, to which Rothpletz refers, is to its outcrops in the upper limits of the city which are on the lower slopes of Mount Helena, and not to the Cambrian limestone which forms the cliffs and steep slopes well up on the mountain side above the city streets. Outcrops of the Helena limestone are best seen in the city in ditches and cellar excavations for houses.

Rothpletz, after speaking of his reviewing the literature accessible to him, says: [1]

> Prepared with this information, I began at Helena my investigations, which had as their object to find pre-Cambrian fossils, and before going into the discussion of the fossils which I found there, I will next describe the geological conditions as, according to my observations, they appear to me to exist.

The description of his examinations about the city of Helena that follows, clearly indicates that he did not have a clear conception of the pre-Cambian formations exposed in the vicinity of Helena. He confuses the Spokane shales and the Marsh shale with the Empire shale, and the Helena limestone with the Cambrian limestones. On page 9,[2] in speaking of limestones on both sides of the north and south Oro Fino Gulch fault (*O-O* on map), which displaces the formations on the lower eastern slopes of Mount Helena, he says that the Flathead quartzite is not exposed on the northwest side of the fault, but "according to its petrographic character, the limestone itself thus corresponds sufficiently to the Helena limestone, as Walcott has described it, so that there can be no doubt as to the identity of both. The oolitic limestone layers are especially characteristic. . . . ."

On page 10,[3] he states that the northeast slope of Mount Helena above the quarry is constructed exclusively of such Helena limestones, up to the terrace-like shoulder, upon which the real summit mass first rises, and upon the shales which occur at the terrace-like shoulder. He describes the summit limestone [dolomite] as having a thickness of 250 meters (812+ ft.), or more. He considers

[1] Rothpletz, p. 8, first new paragraph.

[2] Idem, p. 9, line 37, to p. 10.

[3] Idem, p. 10, line 3.

(p. 11 [1]) that the shale on the terrace-like shoulder is interbedded in the Helena limestone, according to which the summit dolomite must certainly be identical with the latter (Helena limestone). He considers this view feasible because according to Walcott the Helena limestone has a thickness of 2,400 feet (732 m.). He concludes further that the Flathead quartzites mentioned by Walcott were to be expected in the layer above the summit dolomite. (This would be the position of the Dry Creek shale of Weed, p. 269.)

According to Weed and the U. S. Geological Survey geologists (Barrell, Griswold) who have studied the section, the summit dolomite referred to is the Cambrian, Pilgrim limestone of Weed; the shale beneath it, the Park shale of Weed; and the limestone beneath the shale on the terrace-like shoulder referred to above, the Cambrian Meagher limestone which is underlain by the Wolsey shale, and this by the Flathead quartzite.[2]

Confusion in identification of the pre-Cambrian Helena limestone.—Rothpletz was unfortunate in his location and identification of the Helena limestone.

My note on the section reads as follows: [3]

> Crossing the valley of the Missouri River from Whites Canyon directly westward 10 miles to the Spokane Hills, on the west side of the river, one finds a syncline of Cambrian resting directly on the red Spokane shales. Continuing westward on the same line to the city of Helena, a distance of 14 miles, the Cambrian sandstones are found resting on shales 250 feet above the Helena limestone, or fully 3,000 feet above the contact horizon in the Spokane Hills.

Looking at the map (pl. 39), we find directly east of Mount Helena the outcrop of the Helena limestone (*Ah*) extending across the central portion of the city in a southeasterly direction to where it is cut off by the eruptive quartz monzonite (*qm*). Above the Helena limestone (west of it) an area of the Empire shale (*Ae*) occurs above it and beneath the Cambrian Flathead quartzite (*Cf*). This shale is the 250 feet of shale referred to in the above-quoted paragraph. In order to avoid the quartz monzonite area and to take his diagrammatic section across the strike, I carried the section south of the suburb of Lenox (*W-W* on map) as described by him [4] as follows:

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[1] Rothpletz, p. 11, line 15.

[2] See section, p. 263.

[3] Pre-Cambrian Fossiliferous Formations, Bull. Geol. Soc. of America, Vol. 10, 1899, p. 211.

[4] Idem.

Following the line of contact to the southeast for 1 mile, the Cambrian sandstones may be seen resting directly on the massive beds of the Helena limestone, a slight unconformity occurring at the point of contact, as shown by figure 3. A mile farther to the southeast there are 6 feet of shales above the limestone, a slight unconformity being shown between it and the Cambrian. The section east from Helena extends downward through some 2,000 feet or more of (Helena) limestone and interbedded shales and several hundred feet of siliceous, greenish shales before reaching the red Spokane shales, which underlie the Cambrian in the Spokane Hills.

I there found the section more complete from the Spokane shales (*As*) up to the unconformity at the base of the Cambrian Flathead quartzite (*Cf*), and it was in this part of the section that he obtained his estimate of 2,400 feet[1] (731 m.) or more for the thickness of the Helena limestone (*Ah*). It was unfortunate that I did not make this location clear as it would probably have led Rothpletz to look there for the Helena limestone and not to assume that the higher Cambrian limestones of Mount Helena were typical representatives of the Helena limestone.

Once having identified the Cambrian limestone of the upper portions of Mount Helena as the pre-Cambrian Helena limestone which occurs far below and beneath the Empire shale in the more level slope occupied by the city streets, there was little chance of Rothpletz getting the true relations of the Cambrian formations and the underlying pre-Cambrian Helena limestone in the faulted and displaced area south of the suburb of Lenox.

Another confusing condition is the contact on the strike of pre-Cambrian Helena limestone (*Ah*) and the Cambrian limestone (*Cls*). By looking at the map (pl. 39) we find that southeast of the suburb of Lenox and about 1.5 to 2 miles southeast of the thickly built up south section of the city an area of Cambrian and pre-Cambrian strata has been pushed to the northeast one-half mile between the fault lines *A-A* and *B-B*, as shown on the map. This area includes exposures in the section from the base upward of the Empire shale (*Ae*), Helena limestone (*Ah*), and Marsh shales (*Am*) of the Algonkian, and above the latter the Cambrian Flathead quartzite (*Cf*) and the several shales and limestones (*Cls*) of the Cambrian before the overlying Devonian limestones (*Dj*) are met with higher up on the hill slopes. The displacement of this great mass of shales, sandstones and limestones has brought in contact on the strike at *x* (on the eastern fault line (*B-B*)) the pre-Cambrian Helena limestone (*Ah*) and the Cambrian limestones and shales (*Cls*) in such a manner as to cause the outcrop of the Cambrian limestone to be apparently a direct con-

[1] Pre-Cambrian Fossiliferous Formations, Bull. Geol. Soc. of America, Vol. 10, 1899, p. 211.

tinuation of the pre-Cambrian Helena limestone. This contact extends on a north-northeast and south-southwest line for over 1,000 feet (305 m.).

To one who had seen the Cambrian limestones on Mount Helena and mistaken them for the pre-Cambrian Helena limestone, it would be most natural to conclude that not only were the Cambrian limestones the same as the pre-Cambrian Helena limestone, but that the great mass of the Helena limestone southeast of the fault *B-B* was also of the same geological age as the Cambrian limestones.

Rothpletz interpretation of Weed's Cambrian as given in Butte report.—In speaking of the Cambrian section described in Weed's report upon the Butte district,[1] Rothpletz states in substance that, according to Weed, immediately beneath the black Jefferson limestones the shales and limestones of the Cambrian with their basal quartzites rest on the shales and interbedded sandstones of the Belt formation, and further,[2] that " Walcott has, however, separated a part of this thus (above) delimited Cambrian, namely, the Helena limestone and the Marsh shales, and assigned it to the Belt formation. What then still remains over of Weed's Cambrian at Helena is not stated except that the Flathead sandstone [quartzite] forms the base of the Cambrian."

I do not understand this reference of Rothpletz to the Helena limestone and Marsh shale, as Weed has never to my knowledge included the Helena limestone and the Marsh shale in the Cambrian. It serves to further illustrate the confusion in the mind of Rothpletz as to what the Cambrian limestones were, also as to the Helena limestone. In all the publications of Weed and Walcott, the Cambrian limestones are considered to be above the Flathead quartzite and the Helena limestone unconformably beneath it.

Comparison of Rothpletz and Weed Cambrian sections in the Helena district.—Placing in comparison the Rothpletz and Weed sections in the Helena district we have the following result:

Rothpletz	Weed		
6. Limestone (Helena).	Pilgrim limestone	317 ft.	Cambrian.
5. Shales (Capitol Creek).	Park shale	150 "	
4. Limestone (Helena).	Meagher limestone	400 "	
3. Shales (Empire).	Wolsey shale	420 "	
2. Sandstones (Quartzite).	Flathead quartzite	300 "	
1. Shales.	Marsh shale		Algonkian.
	Helena limestone		

[1] Geology and Ore Deposits of Butte District, Montana. Prof. Paper 74, U. S. Geol. Surv., 1912.

[2] Rothpletz, p. 7, line 9.

In view of the data and discussion already presented I do not think it necessary to comment further upon the two sections.

UNCONFORMITY BETWEEN THE CAMBRIAN AND PRE-CAMBRIAN

Having concluded from stratigraphic and paleontologic evidence that there was no unconformity or discordance between the Cambrian and pre-Cambrian at Helena, Rothpletz next proceeds to argue that because the evidence of non-conformity is not readily seen at Helena, Montana, it is quite probable that it does not exist. It was quite natural that he did not discover it about Helena for two reasons. *First,* because it is not very clearly shown. *Second,* he was looking for it within the Cambrian section and not below the Cambrian and above the Helena limestone of the pre-Cambrian (see pp. 279-281).

Grand Canyon section.—If Rothpletz had studied the section at the Grand Canyon of the Colorado River when there in 1913,[1] he might have obtained a very clear conception of the unconformity between the Cambrian and pre-Cambrian. In that section[2] the entire pre-Cambrian sedimentary series of nearly 12,000 feet of sandstones, shales, and limestones were tilted, faulted, more or less broken, and eroded nearly to base level before the transgressing Cambrian sea covered it with beach gravel and sands, arenaceous and calcareous muds in which fragments of an abundant Middle Cambrian fauna were buried. This great unconformity has been illustrated and described several times,[3] but Rothpletz does not refer to it in his memoir, although it is the one great locality where Nature has laid open the history of a great, unmetamorphosed, sedimentary series of pre-Cambrian formations corresponding in stratigraphic position and character with the Belt series of Montana. As giving some conception of the unconformity, a section is inserted here (fig. 11) showing the unconformity between the Cambrian Tapeats sandstone and the pre-Cambrian Grand Canyon series of formations. Four photographs taken in the Grand Canyon are also reproduced in which the unconformity is finely shown (pls. 40-43).

Bow River Valley section.—Rothpletz refers to my description[4] of the Bow River section of Alberta where the Lower Cambrian is

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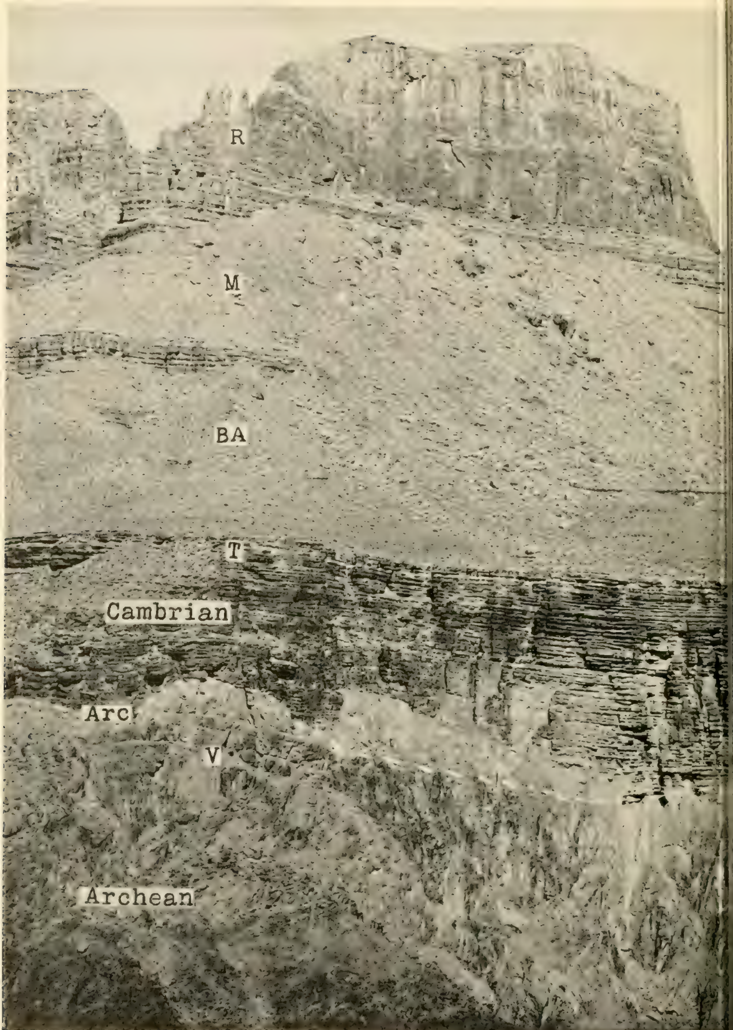
[1] Rothpletz, p. 4.

[2] Walcott, Fourteenth Ann. Rept., U. S. Geol. Surv., 1895, pp. 507-519. Idem, Bull. Geol. Soc. America, Vol. 1, 1889, pp. 51-56, figs. 1-9.

[3] Powell, Exploration Colorado River of the West, 1875, p. 212, fig. 79.
Walcott, 1895, Fourteenth Ann. Rept., U. S. Geol. Surv., pp. 507-517.
Noble, Bull. U. S. Geol. Surv., No. 549, 1914, p. 65, plates 9 and 18.

[4] Smithsonian Misc. Coll., Vol. 53, 1910, p. 426.

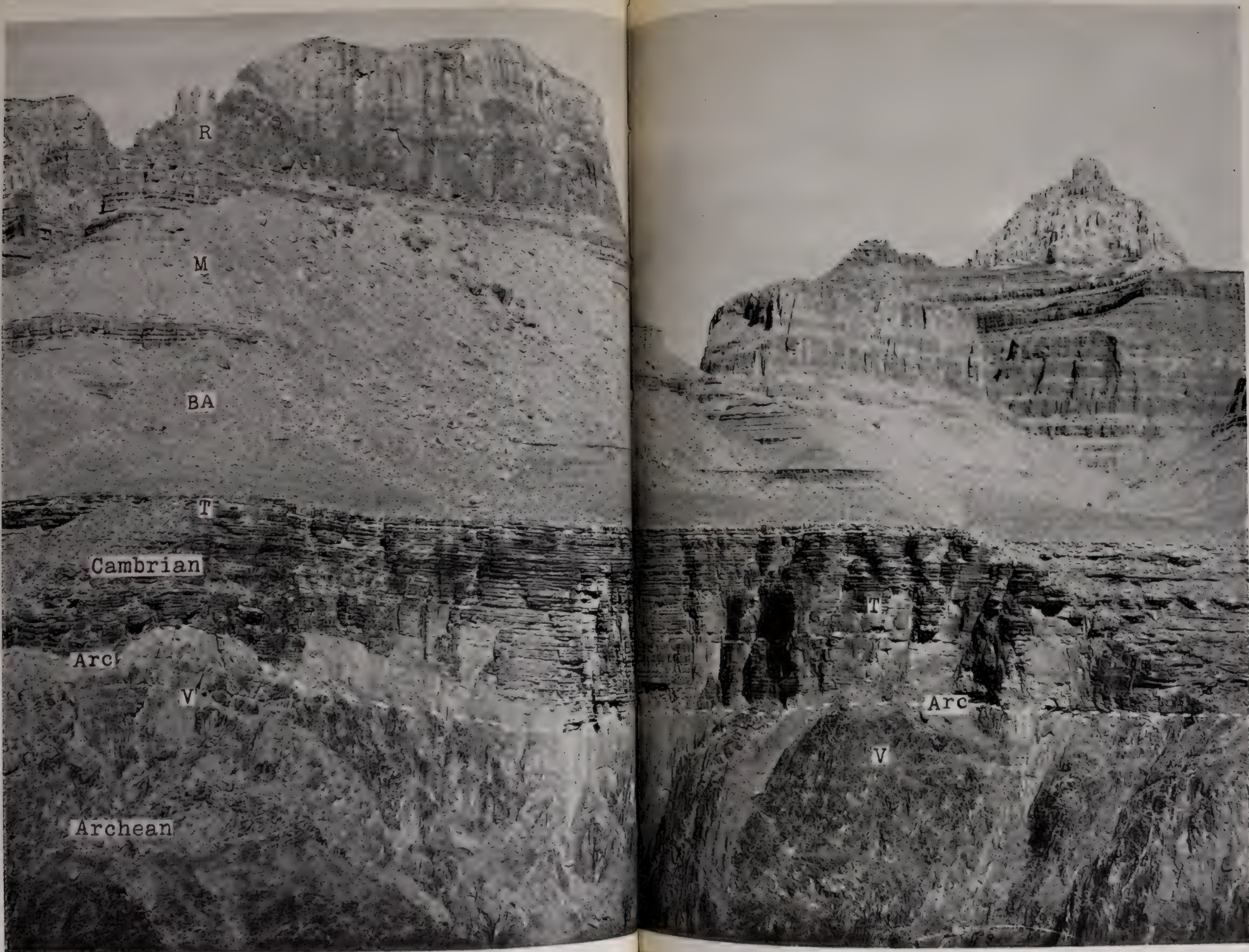


Unconformable contact on line (*Arc*) between Archean (*V* = Vishnu series) and Cambrian (*T* = T
forms terraced slope, and in turn is overlain by Cambrian Muav limestone (*M*) and by cliffs of gre
Isis" rests on Carboniferous sandstone.

Locality: North side of Grand Canyon of the Colorado River, Arizona, below Bright Angel Canyon.
This photograph and also plates 41, 42, and 43 taken by Norman W. Carkhuff, chief photographer
Lettering on plates 40-43. *Carboniferous:* *K* = Kaibab limestone; *C* = Coconino sandstone; *Ss*
Muav limestone; *BA* = Bright Angel shale; *T* = Tapeats sandstone. *Algonkian:* *Un* = Unkar series.
unconformity between Algonkian and Cambrian.

tone). Tapeats (T) sandstone overlain by Cambrian Bright Angel (BA) formation which
(R) Carboniferous limestone. High above on right Carboniferous limestone of "Temple of

ogical Survey, under direction of Walcott, in 1901.
upai formation; Ss = Sandstone of Supai formation; R = Redwall limestone. *Cambrian:* M =
= Vishnu series. Aa = line of unconformity between Archean and Algonkian. Ac = line of



Unconformable contact on line (*Arc*) between Archean (*V*=Vishnu series) and Cambrian (*T*= sandstone). Tapeats (*T*) sandstone overlain by Cambrian Bright Angel (*BA*) formation which forms terraced slope, and in turn is overlain by Cambrian Muav limestone (*M*) and by cliffs of g[...] Wall (*R*) Carboniferous limestone. High above on right Carboniferous limestone of "Temple of Isis" rests on Carboniferous sandstone.

Locality: North side of Grand Canyon of the Colorado River, Arizona, below Bright Angel Ca[...]

This photograph and also plates 41, 42, and 43 taken by Norman W. Carkhuff, chief photograp[...] Geological Survey, under direction of Walcott, in 1901.

Lettering on plates 40-43. *Carboniferous: K*=Kaibab limestone; *C*=Coconino sandstone; [...] Supai formation: *Ss*=Sandstone of Supai formation; *R*=Redwall limestone. *Cambrian: M*=Muav limestone; *BA*=Bright Angel shale; *T*=Tapeats sandstone. *Algonkian: U*=Unkar series[...] V=Vishnu series. *Aa*=line of unconformity between Archean and Algonkian. *Ac*=line of unconformity between Algonkian and Cambrian.

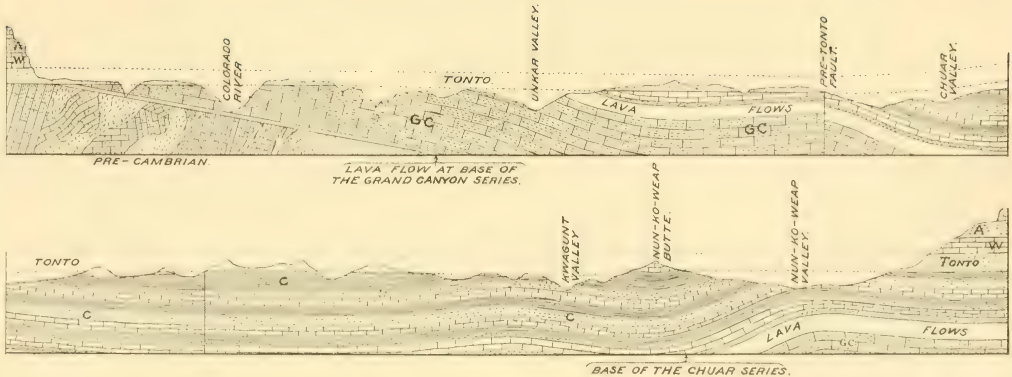


FIG. 11.—Grand Canyon Section. This section crosses the Algonkian strata nearly at right angles to their strike and illustrates the unconformity between the Cambrian and Algonkian rocks. The Cambrian (Tapeats sandstone) has been removed by erosion on the direct line of the section, but it is shown on the sides of the canyon as indicated by the dotted lines. *GC* and *C*, Grand Canyon and Chuar formation, or the strata referred to the Algonkian. *T*, the Tapeats sandstone of the Cambrian. *W*, Redwall limestone of the Lower Carboniferous. *A*, Aubrey sandstone of the Carboniferous.

unconformably resting on the pre-Cambrian Bow River sedimentary series. His criticism of this section is that I did not graphically illustrate the unconformity, and the same comment is made on the diagrammatic section near Helena, Montana.[1]

Of the Bow River Valley unconformity I wrote:[2]

Viewed in a restricted way, much of the pre-Cambrian surface was regular and the Cambrian rocks appear to be conformable to the subjacent pre-Cambrian strata. All about the sides of the valley the strata of the two formations, Fairview of the Cambrian and Hector of the Algonkian, dip away at about the same angle, but, when we apply the test of the varying thickness of the basal Cambrian conglomerate and the difference in the character of the upper beds of the Algonkian in different places, we at once become aware that the pre-Cambrian surface is more or less irregular, and that when the Cambrian sea transgressed over the area now included in the Bow Valley it found a broadly irregular surface with low hills and broad level spaces covered with a deep mantle of disintegrated rock. It washed out the muds and carried them away and deposited the sand and pebbles of its advancing beaches over and around the irregularities of the pre-Cambrian surface.

The unconformity is well shown at Fort Mountain, where the basal Cambrian is formed of massive layers 4-10 feet thick, which usually rest directly on the Hector shale (pre-Cambrian). In places, however, slight hollows in the shale are filled with thin layers of a more or less ferruginous sandstone that was deposited by gentle currents prior to the deposition of the massive conglomerate layers. The lower 10-20 feet of this conglomerate contain rounded and angular fragments of the subjacent pre-Cambrian formations (fig. 1, pl. 46). The Cambrian sea was evidently transgressing across the dark, siliceous shales of the pre-Cambrian land and reducing them to rolled pebbles, angular fragments, and mud. The mud gave origin to small lentiles of shale similar in character to the shale below the unconformity, while lentiles of sandstone of greenish tint indicate that fine material was being derived from still older pre-Cambrian formations than the shale. . . . .

Of greater importance is the evidence that the sediments of the two periods were deposited under different physical conditions. The Cambrian sandstones are composed of clean, well-washed grains, and the Cambrian calcareous and argillaceous shales were deposited as muds off shore along with the remains of an abundant marine life. The Hector shales of the pre-Cambrian are siliceous and without traces of life; the sandstones are impure and dirty, with the quartz grains a dead milky white, or glassy and iron stained. The sediments forming them were evidently deposited in relatively quiet muddy waters, and I think in fresh or brackish waters.

It should be noted that in the Bow River Valley section the *Lower* Cambrian rests on the pre-Cambrian, while in central Montana, about the Belt Mountains, it is the *Middle* Cambrian that is at the base of the Paleozoic series.

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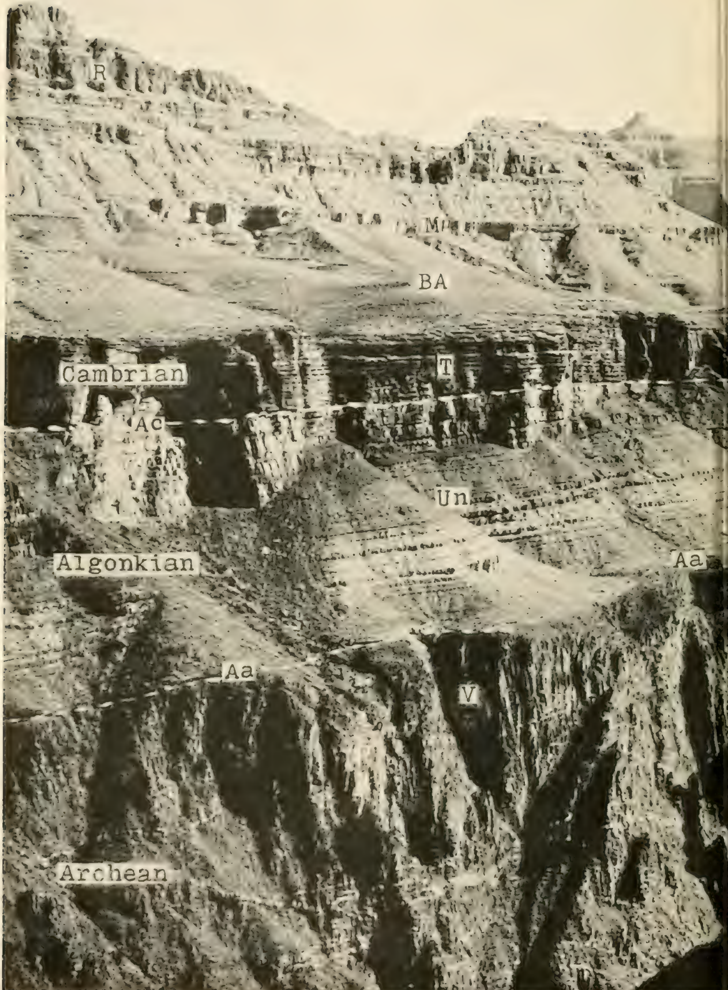
[1] Rothpletz, p. 22.

[2] Pre-Cambrian Rocks of the Bow River Valley, Alberta, Canada. Smithsonian Misc. Coll., Vol. 53, 1910, pp. 426-427.



Unconformable contact on line (*Aa*) between Archean (*V* = Vishnu series) and Algonkian (*Un* =
side of view on line (*Arc*). In center and left side on line *Ac* the Cambrian (*T*) rests unconformabl
Locality: North side of Grand Canyon of Colorado River, Arizona, below Bright Angel Canyon,
One of the finest of the exposures showing the pre-Cambrian surface graded by erosion across the
Muav limestone (*M*) form terraces up to base of Carboniferous Red Wall limestone (*R*).

ies); also between Cambrian (T=Tapeats sandstone) and Archean (V= Vishnu series) on right
Algonkian (Un=Unkar series).
from mouth of Bass Canyon.
and Algonkian formations. The two higher formations of Cambrian Bright Angel shales (BA) and

Unconformable contact on line (*Aa*) between Archean (*V*=Vishnu series) and Algonkian ([illegible] series); also between Cambrian (*T*=Tapeats sandstone) and Archean (*V*= Vishnu series) on right side of view on line (*Arc*). In center and left side on line *Ac* the Cambrian (*T*) rests unconfor[illegible] the Algonkian (*Un*=Unkar series).

Locality: North side of Grand Canyon of Colorado River, Arizona, below Bright Angel Can[illegible]cross from mouth of Bass Canyon.

One of the finest of the exposures showing the pre-Cambrian surface graded by erosion acros[illegible]ean and Algonkian formations. The two higher formations of Cambrian Bright Angel shales (*BA*) and Muav limestone (*M*) form terraces up to base of Carboniferous Red Wall limestone (*R*).

Belt Mountains—Helena section.—By oversight Rothpletz failed to realize that my diagrammatic section to which he refers so frequently was not drawn to illustrate the actual minor unconformities at Helena, but to show the great unconformity indicated by the absence in the Spokane Hills of the Empire shales, Helena limestone, and Marsh shale beneath the Flathead quartzite of the Cambrian.

The Flathead quartzite rests on the Spokane shales in the Spokane Hills and also to the southeast on Deep Creek east of Townsend, Montana. The diagrammatic section is here reproduced as figure 10 (p. 263).

Of the unconformity between the Belt terrane and the Cambrian I wrote in 1899:[1]

> *Extent and character of recognized contacts.*—The contact of the Flathead Cambrian sandstones with the rocks of the Belt terrane may be observed along a great extent of outcrop on the eastern, southern, and western sides of the Little Belt and Big Belt Mountains. Fully 200 miles or more of outcrop may be followed, along which frequent contacts may be observed. On the eastern side, in the vicinity of Neihart, the unconformity between the Cambrian and underlying Belt terrane is clearly evident, though the angular unconformity is generally slight and has been recognized only on Sawmill Creek. Four miles north of Neihart the Cambrian rests on a nearly level surface of (Archean) crystalline schists. West of Neihart it rests on the Neihart (Algonkian) quartzites. On O'Brien Creek, a few miles southwest of the town, it rests on black shales (Chamberlain Algonkian shales), of which there is less than 300 feet in thickness between the Cambrian and the top of the Neihart quartzite. On Chamberlain Creek and upper Belt Creek, 6 miles southeast of Neihart, the Cambrian rests on the (Algonkian) Grayson shales, while along the stage road up Sawmill Creek it is superimposed on the red (Algonkian) Spokane shales. The only exposures on the eastern slope of the Little Belt range, those of the south fork of the Judith, show the Cambrian resting on the drab Grayson shales. These are the only instances known where the red Spokane shales are wanting beneath the Cambrian. Whether the shoreline conditions, which are known to have existed near Neihart during the period when the Belt terrane was formed, caused a wedging out of the beds to the north, so that the Cambrian rests on different horizons at this locality, or whether pre-Cambrian erosion was extensive enough to pare down the exposed edges of the beds, is not certain from the evidence, though the latter view seems improbable. Similar conditions prevailed southward in the Bridger range.
>
> In the north end of the Bridger range, east of Gallatin valley, the Cambrian is seen resting on the Belt terrane, which at this locality does not show its typical development, but consists largely of coarse sandstones and grits composed of Archean débris. In the south end of this range, but a few miles distant from the former exposures, the Belt terrane is entirely wanting, and the Cambrian rests directly on the Archean schists, as it does at Neihart. The

[1] Bull. Geol. Soc. America, Vol. 10, pp. 210-215.

character of the Belt beds indicates, moreover, that the Cambrian overlaps the Belt (Period) shoreline. Forty miles southeast of Neihart, in the Deep Creek and Grayson Creek sections, on the southwestern slope of the Big Belt Mountains, the Flathead rests on the Spokane shales, but at a higher horizon than at the head of Sawmill Canyon. Twenty-two miles north-northeast of Deep Creek in Whites Canyon, the full thickness of the Grayson shale and also about 1,000 feet of the (Algonkian) Helena limestone occur beneath the Cambrian sandstones.

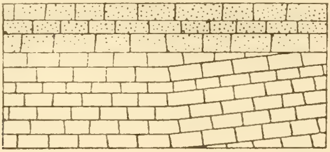


FIG. 12. — Unconformity between Helena Limestone and Cambrian Flathead Sandstone. The locality indicated is 1.25 miles southeast of the suburb of Lenox, and 2 miles southeast of the Capitol building at Helena, Montana.

Crossing the valley of the Missouri River from Whites Canyon directly westward 10 miles to the Spokane Hills, on the west side of the river, one finds a syncline of Cambrian resting directly on the red Spokane shales. Continuing westward on the same line to the city of Helena, a distance of 14 miles, the Cambrian sandstones are found resting on shales 250 feet above

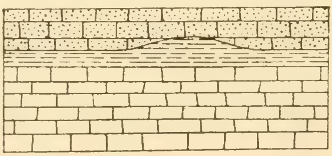
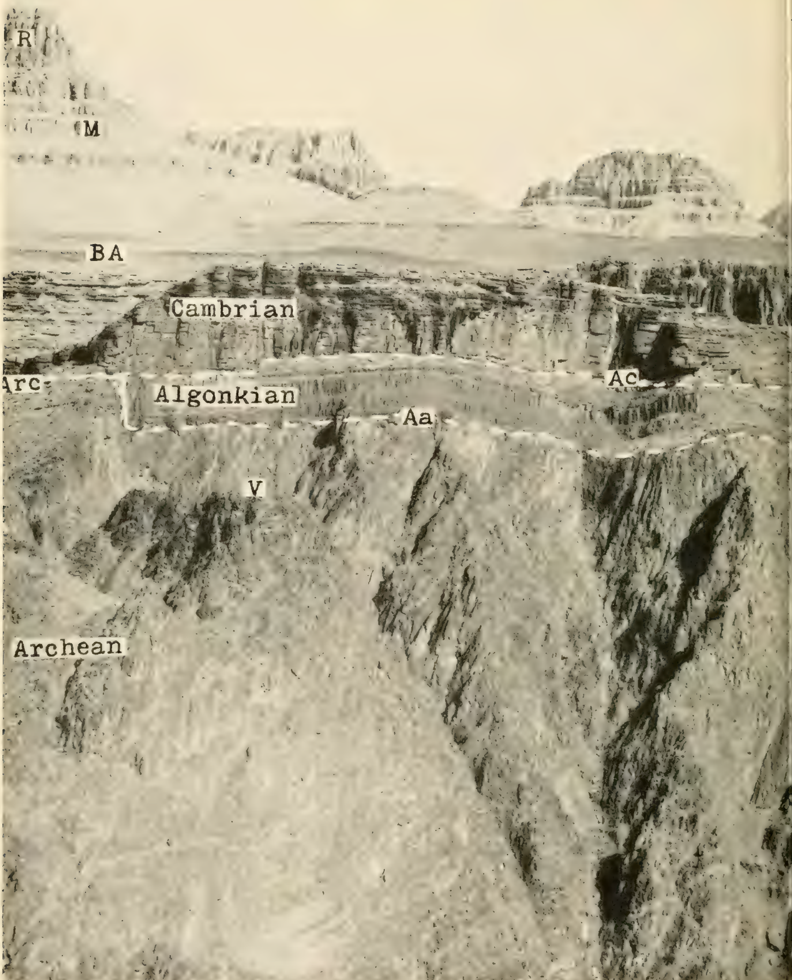


FIG. 13. — Unconformity between Marsh Shale and Cambrian Flathead Sandstone. The locality indicated is about 1 mile southeast of the locality of fig. 12, or 3 miles southeast of the Capitol building.

the Helena limestone, or fully 3,000 feet above the contact horizon in the Spokane Hills. Following the line of (the Flathead-quartzite-Spokane shale) contact to the southeast for 1 mile, the Cambrian sandstones may be seen resting directly on the massive beds of the Helena limestone, a slight unconformity occurring at the point of contact, as shown by figure 12. A mile farther southeast there are 6 feet of shale above the limestone, a slight unconformity being shown between it and the Cambrian (fig. 13). The section east from Helena extends downward through some 2,000 feet or more of limestone and interbedded shales and several hundred feet of siliceous, greenish shales



Unconformable contact on line (*Aa*) between Archean (*V* = Vishnu series) and Algonkian (*Un* = Unkar serie removed latter to left over Archean before deposition of the Cambrian (*T* = Tapeats sandstone). The unconforn the Algonkian (*Un* = Unkar) series elsewhere on plate; more fully shown in plate 43.

Locality: North side of Grand Canyon of Colorado River, Arizona, opposite Grand View trail. This is wh Archean at *A*. (American Jour. Sci., 3d ser., Vol. 26, 1883, p. 438, third paragraph.)

ve bed of basalt rests on the Archean. Erosion cut across the entire Algonkian (*Un*=Unkar) series and
of Cambrian is between Archean (*V*=Vishnu) series on the left side of plate on line (*Arc*), and between

nade by Walcott during winter of 1881-1882 came down over Tonto terrace and Algonkian cliffs to the

Unconformable contact on line (*Aa*) between Archean (*V*=Vishnu series) and Algonkian (*Un*=Unkar s[illegible]assive bed of basalt rests on the Archean. Erosion cut across the entire Algonkian (*Un*=Unkar) series and removed latter to left over Archean before deposition of the Cambrian (*T*=Tapeats sandstone). The unc[illegible]ase of Cambrian is between Archean (*V*=Vishnu) series on the left side of plate on line (*Arc*), and between the Algonkian (*Un*=Unkar) series elsewhere on plate; more fully shown in plate 43.

Locality: North side of Grand Canyon of Colorado River, Arizona, opposite Grand View trail. Th[illegible]on made by Walcott during winter of 1881-1882 came down over Tonto terrace and Algonkian cliffs to the Archean at *A*. (American Jour. Sci., 3d ser., Vol. 26, 1883, p. 438, third paragraph.)

before reaching (north of railway tracks) the red Spokane shales, which underlie the Cambrian in the Spokane Hills.

The relations of the Cambrian and the subjacent Belt terrane on the line of the section from Helena eastward across the Spokane Hills to the Big Belt Mountains are indicated in the diagrammatic section, figure 10, (p. 263).

Northwest of Helena the contact between the Cambrian and the Belt terrane is followed to the crossing of Little Prickly Pear Creek, 6 miles west of Marysville. The Helena limestone outcrops all along the hills and gulches, and at Marysville the subjacent Empire shales occur beneath the limestone. West of the Marysville Canyon area the siliceous beds dip from 10 to 15 degrees to the northwest and pass above into the Helena limestone series, on which rest the Marsh shales. Crossing east-northeast, to the Gates of the Mountain, on the Missouri, 18 miles north of Helena, one finds the Cambrian sandstones resting on the red Spokane shales. This contact is again well shown on the eastern side of the Missouri River, on the road to Beaver Creek. On Beaver Creek the Cambrian rests directly on the Spokane shales, which, with the Grayson shales, constitute a thickness of several thousand feet between the Newland limestone and the base of the Cambrian. The contact at the crossing of Soap and Trout Creeks, to the northeast, is essentially the same as at Beaver Creek and the Spokane Hills, although there is a variation in the beds of the Grayson, which come in contact with the Cambrian.

At most of the outcrops where the lower beds of the Flathead (Cambrian) sandstones come in contact with the Belt rocks the dip and strike of the two are usually conformable, so far as can be determined by measurement. This holds good all around the great Big Belt Mountain uplift. It is only when the contacts are examined in detail, as near Helena, that the minor unconformities are discovered (figures 12 and 13), and only when comparisons are made between sections at some distance from each other that the extent of the unconformity becomes apparent.

Explanation of apparent conformity.—The reason for the apparent conformity in strike and dip between the two groups appears to be as follows: In pre-Cambrian time the Belt rocks were elevated a little above the sea, and at the same time were slightly folded, so as to form low ridges. One of these ridges is now the base of the Spokane Hills, where the Helena limestone (and Empire shales) and the upper portion of the Spokane shales were removed by erosion in pre-Cambrian or early Cambrian time. Usually there is very little, if any, trace of this pre-Cambrian erosion contained in the basal sandstones of the Cambrian. On Indian Creek, however, west of Townsend, which is on the strike of the Spokane Hills uplift, the basal bed of the Cambrian is made up almost entirely of fragments of the subjacent Spokane shales. Fragments of these shales were also observed in the sandstones of the Cambrian in the Little Belt Mountains near Wolsey postoffice. These illustrations are exceptional, the base of the Cambrian sandstone being formed usually of a clean sand, such as might be deposited where the sea was transgressing on the land.

The gentle quaquaversal uplift of the Belt rocks (of the Big Belt Mountains) gave them a slight outward dip toward the advancing Cambrian sea, so that the sediments laid down on the Belt rocks were almost concentrically conformable to them. Subsequent orographic movements have elevated the Belt rocks into mountain ridges and have tipped back and in many instances folded the superjacent Cambrian rocks, but the original concentric conformity

between the beds of the two series remains wherever the lines of outcrop are at right angles to the plane of erosion of the Cambrian sea which cut across the Belt rocks toward the center of uplift.

Extent of unconformity—The extent of the unconformity between the Belt and the Cambrian may never be ascertained, as there is no section known where the sedimentation is unbroken from the Belt to the Cambrian. The greatest example of erosion is in the Spokane Hills, where the Helena limestone, with its superjacent Marsh and subjacent Empire shales, has been removed (fig. 11, p. 263). In other localities the red Spokane shales have been largely removed, but some of these are so far from the Spokane Hills section that it may be urged that they were not originally deposited in any greater thickness than is shown in the sections. The unconformity now known proves that in late Algonkian time an orographic movement raised the indurated sediments of the Belt terrane above sea-level, that folding of the Belt rocks formed ridges of considerable elevation, and that areal erosion and the Cambrian sea cut away in places from 3,000 to 4,000 feet of the upper formations of the Belt terrane before the sands that now form the middle Cambrian sandstones were deposited.

I think that an unconformity to the extent indicated is sufficient to explain the absence of lower Cambrian rocks and fossils and to warrant our placing the Belt terrane in the pre-Cambrian Algonkian system of formations.

Epeirogenetic unconformities.—Rothpletz seeks to explain the unconformity at the base of the Flathead quartzite by considering it as only the result of the filling up of a basin by sediment and the subsequent depression of the basin so that sedimentation was resumed, as has been the case many times in the history of sedimentary deposition on the North American Continent. In advancing this view, however, he fails to consider the great unconformity in the Grand Canyon area where profound faulting and displacement followed by prolonged erosion took place prior to the Cambrian transgression and sedimentation; the equally great disturbance and erosion in the Llano area of central Texas;[1] and the Spokane Hills uplift east of Helena, where a ridge of the Belt series rocks was eroded so as to remove 3,000 feet or more before the Spokane shales were buried beneath the sands of the transgressing Cambrian sea and the Big Snowy Mountains unconformity (p. 274).

In a recent publication I spoke of the post-Algonkian, pre-Cambrian unconformity as follows:[2]

CAMBRIAN BASAL UNCONFORMITY

From the Robson Peak region of British Columbia and Alberta to Arizona and southern California, a distance of over 1,000 miles (1,600 km.), clear evidence of a transgressing Cambrian sea has been found in many localities, proving conclusively that a general unconformity occurs here between the

[1] Walcott, American Jour. Sci., 3d Ser., Vol. 28, 1884, p. 432.

[2] Problems of Geology, Chap. 4, Yale Univ. Press, 1914, pp. 170-171.

Unconformable contact between the Cambrian (T=Tapeats sandstone) and the finest exposure of A exposed between the Archean as seen in plate 42 and the highest beds of the Algonkian shown on the ri beneath the cliffs of Cambrian (T=Tapeats) sandstone as the outcrop of the latter winds in and out aro the Chuar series (Ch) are beautifully exposed on the west side of the Grand Canyon in the Canyon Valley gressing Middle Cambrian seas covered them with its beach sands

The line of unconformity (Ac) at the base of the Cambrian (T=Tapeats sandstone) cuts across thou The locality is on the north and west sides of the Grand Canyon of the Colorado River, Arizona, opp

etamorphosed strata in the world. Fully 6,000 feet of the Unkar and Chuar series of formations are
ate 43, beneath the Cambrian. The red sandstones of the Unkar series (*Un*) stand out in strong relief
anyons and projecting headlands between them. To the north the sandstones, shales and limestones of
nd Nunkoweap. Everywhere erosion planed these formations down nearly to a level before the trans-

in thickness of the Algonkian (*Un* = Unkar) series on which it rests.
'iew, and where the Colorado River flowing from the north bends to the westward.

Unconformable contact between the Cambrian (T = Tapeats sandstone) and the finest exp... metamorphosed strata in the world. Fully 6,000 feet of the Unkar and Chuar series of formations are exposed between the Archean as seen in plate 42 and the highest beds of the Algonkian shown ... plate 43, beneath the Cambrian. The red sandstones of the Unkar series (Un) stand out in strong relief beneath the cliffs of Cambrian (T = Tapeats) sandstone as the outcrop of the latter winds in and ... canyons and projecting headlands between them. To the north the sandstones, shales and limestones of the Chuar series (Ch) are beautifully exposed on the west side of the Grand Canyon in the Canyon ... and Nunkoweap. Everywhere erosion planed these formations down nearly to a level before the transgressing Middle Cambrian seas covered them with its beach sands

The line of unconformity (Ac) at the base of the Cambrian (T = Tapeats sandstone) cuts across ... feet in thickness of the Algonkian (Un = Unkar) series on which it rests.

The locality is on the north and west sides of the Grand Canyon of the Colorado River, Ariz... and View, and where the Colorado River flowing from the north bends to the westward.

Cambrian and pre-Cambrian. This marked unconformity is the record of the advancing, overlapping Lower Cambrian sea of southwestern Nevada, the Middle Cambrian sea of Utah and Idaho, and finally the Upper Cambrian sea of Colorado and the interior continental area.

The Cambrian rocks may be abruptly conformable upon the Algonkian or Archaean,[1] or apparently conformable, as in areas where there has been very little disturbance of the subjacent Algonkian beds.[2] Over the interior of the continent the Upper Cambrian strata unconformably overlap the Algonkian and Archaean,[3] and there is here no record of any part of the Lower Cambrian period. I do not know of a case of proven conformity with transition deposition between Cambrian and pre-Cambrian Algonkian rocks on the North American continent. In all localities where the contact is sufficiently extensive, or where fossils have been found in the basal Cambrian beds or above the basal conglomerate and coarser sandstone, an unmistakable hiatus has been found to exist. Stated in another way, the pre-Cambrian land surface was formed of sedimentary, eruptive, and crystalline rocks, the deposition of which did not in any known instance immediately precede the Cambrian sediments. Everywhere there is a marked stratigraphic and time break between the known pre-Cambrian rocks and the Cambrian strata of the North American continent.[4]

The Lower Cambrian is characterized in southwestern Nevada by the presence of the Lower Cambrian[5] (Waucobian)[6] fauna, which there ranges through some 4,000 feet (1,220 m.) of strata that have no known line of demarcation at the base to separate the Cambrian from some pre-Cambrian Paleozoic formation. This leads to the hope that still older beds and faunas will be discovered in this region which will establish a base to the Cambrian not entirely founded on unconformable superposition of the Cambrian on pre-Cambrian formations.

In mentioning the pre-Cambrian surface I said:[7]

From the evidence afforded by the stratified rocks and their contained fossils, the first known sediments were deposited in a shallow marine basin that occupied an area now included in southwestern California and adjacent portions of Nevada. The incoming Cambrian sea encountered a land surface deeply disintegrated and more or less eroded nearly to base-level. Compared with the earlier epochs of Algonkian time it was a featureless surface, the elevations caused by folding and uplift in the geosynclines and the adjoining geanticlines of the Cordilleran, Lake Superior, and Appalachian areas of Algonkian time having been largely degraded. The rising waters met with only slight elevations in the Cordilleran trough, as evidenced by the almost entire absence of coarse conglomerates and the presence, above the coarse

[1] Tenth Ann. Rept., U. S. Geol. Surv., 1891, p. 551, fig. 48.

[2] Bull. Geol. Soc. America, Vol. 10, 1899, pp. 210-213.

[3] Tenth Ann. Rept., U. S. Geol. Surv., 1891, pl. 44, pp. 561-562.

[4] Twelfth Ann. Rept., U. S. Geol. Surv., 1892, pp. 546-557.

[5] Tenth Ann. Rept., U. S. Geol. Surv., 1891, pp. 515, 549.

[6] Smithsonian Misc. Coll., Vol. 57, 1912, p. 305.

[7] Problems of Geology, Yale Univ. Press, 1914, Chap. 4: The Cambrian and its Problems in the Cordilleran Region, p. 167.

basal sandstones and fine conglomerates, of deposits of very fine-grained sandstones and mud rocks.[1]

Absence of marine life in the Algonkian sedimentary rocks.—The almost total absence of a definite marine life in the unmetamorphosed limestones, shales, and sandstones of the Belt formations and all Algonkian formations does not apparently appeal to Rothpletz. With every physical condition favorable to the presence and flourishing existence of an abundant marine fauna there has not been in 30 years examination of these formations by many keen-eyed geologists and paleontologists an authentic reported find of a fauna unmistakably marine and allied to the Cambrian faunas. I reported a transient modified marine fauna from the Grayson shales[2] and traces of life in the Grand Canyon series.[3] Later, I recorded algal remains[4] and bacteria[5] from the Newland limestone of the Belt formations, but all of these seem to indicate fresh or brackish water life or a fragment of a marine fauna adjusted to fresh-water conditions. This taken in conjunction with the character of the Algonkian sedimentation seems to point to a non-marine epicontinental origin for the known Algonkian formations.[6]

Further, when speaking of "Pre-Cambrian Continental Conditions," I said:[7]

> The North American continent was larger at the beginning of known Cambrian time than at any subsequent period other than possibly at the end of the Paleozoic and the end of the Cretaceous, when the land was equally extensive. Indeed, it is highly probable that its area was greater then than even now, for no marine deposits containing pre-Cambrian life, as they were laid down in Lipalian[8] time immediately preceding the Cambrian period, have been discovered on the North American continent or elsewhere so far as known.

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[1] Darton has described coarse conglomerates at the base of the Cambrian of the Black Hills, South Dakota, but this is in an early Upper Cambrian formation and far east from the Cordilleran region. It seems to be a local deposit. (Prof. Paper, U. S. Geol. Surv., No. 65, 1909, pp. 12, 13.)

[2] Bull. Geol. Soc. America, Vol. 10, 1899, pp. 235-238.

[3] Idem, p. 232.

[4] Smithsonian Misc. Coll., Vol. 64, No. 2, 1914.

[5] Proc. Nat. Acad. Sci., Vol. 1, p. 256, 1915.

[6] Problems of American Geology, Yale Univ. Press, 1914, Chap. 4: The Cambrian and its Problems, pp. 164-167.

[7] Problems of American Geology, Yale Univ. Press, 1914, Chap. 4: The Cambrian and its Problems, pp. 166-167.

[8] Smithsonian Misc. Coll., Vol. 57, 1910, p. 14 (footnote).

Lipalian (λειπα+αλs) was proposed for the era of unknown marine sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna. It represents the period between the formation (beginning) of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea.

PALEONTOLOGICAL EVIDENCE

The paleontological evidence given by Rothpletz in favor of the Lower Cambrian age of the " Capitol Creek shale " (=Park shale of Weed) is interesting. He tabulates it as follows:[1]

	Lower.	Middle.	Upper Cambrian.
1. *Protospongia* cf. *fenestrata*	×	×	
2. *Rustella edsoni* var. *pentagonalis*	×		
3. *Lingulella helena*		×	
4. *Obolella crassa*	×		
5. *Obolella atlantica*	×		
6. *Acrotreta* cf. *sagittalis*	×	×	×
7. *Kutorgina* cf. *perrugata*	×		
8. *Hyolithes* cf. *billingsi*	×	×	

By the above identification and interpretation of the fossils from the shale a strong case is made out for the Lower Cambrian age of the Park shale of Weed, or as Rothpletz states it: " We conclude that the fauna of the Capitol Creek shale is doubtless Lower Cambrian, but that it very possibly and indeed very probably belongs to an upper horizon of the Lower Cambrian."[2]

I wish I could agree with Rothpletz as to the Lower Cambrian age of the fossils he lists and illustrates, as it would be a great pleasure to me to know that the Lower Cambrian was unconformably superjacent to the Belt series of formations in this section of Montana as it is on the north side of the Bow River Valley in Alberta, Canada.[3] Such a condition would not alter in any way the position of the Helena limestone, which is far below in the pre-Cambrian Belt series.

Stratigraphically (ante p. 281) we have seen by the section of Weed at Mount Helena that the Park shale (=Capitol Creek shale of Rothpletz) is 1,100 feet (335 m.) or more above the base of the Middle Cambrian and 2,455 feet (755 m.) above the base of the Middle Cambrian on Beaver Creek, 20 miles (32 km.) northeast of Mount Helena. This makes it difficult to consider the fauna of the Park (" Capitol Creek ") shale in the Lower Cambrian even though the fossils should appear to favor it. The Wolsey shale is 400 feet (123 m.) below the Park shale in the Mount Helena section, the interval being occupied by the Middle Cambrian Meagher limestone which Rothpletz by error identified as the lower portion of the pre-Cambrian Helena limestone. The fauna of the Wolsey shale zone

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[1] Rothpletz, p. 41.
[2] Idem, p. 41.
[3] Smithsonian Misc. Coll., Vol. 53, 1910, pp. 426-427.

includes at a locality near Wolsey 11 miles (17.7 km.) south of Neihart in the Little Belt Mountains:

Micromitra pealei (Walcott)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella desiderata (Walcott)
Scenella sp. undt.
Dorypyge ? quadriceps (Hall and Whitfield)
Alokistocare ? labrosum Walcott
Asaphiscus calenus Walcott

Six miles (9.6 km.) northwest of Neihart I found at the same horizon:

Micromitra pealei (Walcott)
Obolus tetonensis Walcott
Scenella sp. undt.

Below Sixteen Post Office, in Sixteen Mile Canyon, Meagher County, Montana (Locality 159f):

Alokistocare pomona Walcott
Dolichometopus bessus Walcott

Five miles (8 km.) east-northeast of Logan, and 1 mile (1.6 km.) north of junction of East and West Gallatin Rivers, Gallatin County, Montana:

Obolus (*Westonia*) *ella* (Hall and Whitfield)
Acrocephalites ? majus Walcott
Asaphiscus camma Walcott

The above Wolsey shale fauna is far below the Capitol Creek (Park) shale and above the Flathead quartzite.

When making my examinations about Helena in 1898, the results of which were published in 1899,[1] I found abundant fossil remains in a hard, dark, finely arenaceous or siliceous shale (= Park shale of Weed) on the southeastern slope of Mount Helena about 200 feet (60 m.) above the road in the canyon of Grizzly Gulch which extends down into the southwestern suburb of the city. I followed these shales to the southeast and found similar fossils 2 miles (3.2 km.) southeast of the city (about one-half mile southeast of the suburb of Lenox) at a locality near one to which my attention had been called by Mr. Griswold. The fossils include at both localities:

Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella helena (Walcott)
Hyolithes
Ptychoparia

[1] Geol. Soc. of America, Vol. 10, Pre-Cambrian Fossiliferous Formations.

All of the specimens in the shale are more or less flattened by compression and usually more or less distorted. Frequently the distortion of the brachiopods takes the forms shown by Rothpletz, plate 2, figures 4 to 12; plate 3, figures 3 and 5. When the dorsal valves of *Lingulella helena* are shortened by pressure they are apt to arch up and curve down rapidly on the posterior side; the usually rounded postero-lateral margins also assume a more angular outline.

DETERMINATION OF GENERA AND SPECIES BY ROTHPLETZ, AND NOTES BY WALCOTT

1. Prostospongia cf. *fenestrata* Salter (pl. 2, figs. 2-7, of Rothpletz.)

This form of sponge spicule is met with in both the Lower and Middle Cambrian formations. It is particularly abundant in the shales of the Middle Cambrian. Specific and even generic determination is very difficult.

2. Rustella edsoni var. *pentagonalis* Rothpletz (pl. 1, fig. 10, of Rothpletz).

This is evidently a dorsal valve of *Obolus* (*Westonia*) *ella*, which preserves the concentric striation so characteristic of that species when the outer surface has been removed by clinging to the matrix. *Rustella edsoni*, with which it is identified, has been found only in association with *Olenellus* on Lake Champlain, Vermont, and near York, Pennsylvania, on the eastern side of the continent. *Obolus* (*Westonia*) *ella* is a common form in the Park shale on Mount Helena, and I am surprised that Rothpletz did not find it there and also more abundantly where he collected the fauna southeast of Helena.

For comparison I am illustrating (pl. 44, figs. 6, 7, 8, and 9) dorsal valves of *O.* (*W.*) *ella* from the Park shale on the southeast slope of Mount Helena, also ventral valves which have been shortened and broadened a little by compression. *Obolus* (*Westonia*) *ella* occurs in passage beds between the Lower and Middle Cambrian.[1] It is most abundant in the Middle Cambrian, and rarely if not doubtfully present in the Upper Cambrian.

3. Lingulella helena (Walcott) (pl. 2, figs. 1 and 2, of Rothpletz).

This is very abundant in the Park shale on the southeast slope of Mount Helena, also in the same band of shales where outcrops occur

[1] The stratigraphic position of the beds containing this fauna in northern Montana is open to discussion. I have long considered them as doubtfully Lower Cambrian or Middle Cambrian. They may be claimed for either until more detailed studies are made at the typical localities where they occur.

southeast of the city of Helena. In the vicinity of the faults that cut the shale the specimens are apt to be more distorted than from the shales on Mount Helena. Rothpletz gives an excellent petrographic description of the shale. In speaking of the subsequent alteration of the shales he says, "Simultaneously with the origin of the compression-bedding there occurred an inner movement in the entire rock mass, which led in places to distortion, elsewhere to compression. On this account the nearly circular fossil shells frequently retain a lengthened form, and this is one of the difficult conditions in the determination of the fossils." [1]

The ventral valves of *L. helena* illustrated by Rothpletz (pl. 2, figs. 1, 2) are normal in form and size, but he does not name and illustrate the dorsal valve except under other names. To me all of his figures 4 to 12, plate 2, and figures 3 and 5, plate 3, are in size and in such characters as are preserved, representatives of the dorsal valves of *L. helena* (see pl. 44, figs. 1-5 of this paper).

4. Obolella crassa (Hall) (pl. 2, figs. 4, 5, 7-12, of Rothpletz).

This is one of the greatest surprises of the Rothpletz determinations. The shells illustrated are small, the largest according to Rothpletz 5 to 7 mm. in diameter, and the shell is preserved as phosphate of lime. *Obolella crassa* is a species with the valves from two to three times the size of the shells figured by Rothpletz [2] and the valves are thick and built up of layers of carbonate of lime, although originally they may have been calcareo-corneous. All known specimens of *Obolella crassa* have been found in connection with the Lower Cambrian *Olenellus* fauna at localities on the eastern side of the North American continent.

To one acquainted with *Obolella crassa* as the species occurs in the limestones of the Straits of Belle Isle, Labrador, and the St. Lawrence River province, it seems impossible to consider the distorted Park shale specimens as even superficially related to *Obolella crassa* or even to the genus *Obolella*.

The Rothpletz figures referred to *Obolella* appear to illustrate more or less distorted dorsal valves of *L. helena*.

5. Obolella atlantica Walcott (pl. 2, figs. 3 and 6, of Rothpletz).

Figure 3 appears to represent a fragment of ventral valve of *Lingulella helena*, and figure 6 a distorted dorsal valve.

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[1] Rothpletz, p. 27, middle of last paragraph, going over to p. 28.

[2] Monogr. U. S. Geol. Surv., Vol. 51, 1912, pl. 54.

6. *Acrotreta* cf. *sagittalis* (Salter) (pl. 3, fig. 10, of Rothpletz).

This is a Middle Cambrian and Upper Cambrian species of Europe and a Middle Cambrian species in the Atlantic Coast provinces of North America. The specimen figured by Rothpletz is a compressed ventral valve and is much more likely to be *Acrotreta depressa* (Walcott) [1] of the Middle Cambrian of the Rocky Mountains.

7. *Kutorgina* cf. *perrugata* Walcott (pl. 3, fig. 1, of Rothpletz).

This is a figure of an undeterminable fragment of a large brachiopod.

8. *Hyolithes* cf. *billingsi* Walcott (pl. 3, figs. 2 and 4, of Rothpletz).

This is a very common form of *Hyolithes* and is abundant in the Park and Wolsey shales at Helena and elsewhere.

The fragments of trilobites figured by Rothpletz on plate 3 have no special significance except that they are of Cambrian age.

COMMENT ON PALEONTOLOGICAL EVIDENCE

Rothpletz does not seem to have established a strong case for the Lower Cambrian age of the Park shale fauna. There does not appear to be the slightest foundation for assuming that because there are some superficial resemblances in form between the distorted shells in the shale and the various species with which he has identified them, the fauna is, therefore, of Lower Cambrian age. The fossils are unlike the Lower Cambrian species with which they have been identified, and such a known association of species does not occur at any one locality and zone anywhere in the world.

The impression made upon me is that Rothpletz once having been misled by his interpretation of the stratigraphy was unconsciously influenced to determine his fossils as of Lower Cambrian age. The purpose for which he went to Helena, that is, to discover pre-Cambrian fossils in the Belt formations,[2] would have been served by Middle Cambrian fossils quite as well, provided they came from what had previously been identified as a pre-Cambrian formation. The discovery of fossils in a Middle Cambrian shale at Helena in which they had previously been found is evidently not what Rothpletz thought he was doing either in the field or in the laboratory.

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[1] Monogr. U. S. Geol. Surv., Vol. 51, 1912, pl. 66, figs. 8, 8*a-c*.

[2] Rothpletz, p. 8.

CONCLUSIONS

The conclusions of Rothpletz's reconnaissance in the vicinity of Helena, Montana, are essentially as stated below, followed by my own conclusions on the results announced by him, the numbering being the same for each set of conclusions.

1. (*Rothpletz*) That the upper limestone No. 6 of his section (p. 281) of Mount Helena is a part of the pre-Cambrian "Helena" limestone of Walcott.

1. (*Walcott*) The Rothpletz limestone No. 6 is the Middle Cambrian, Pilgrim limestone of Weed (p. 281).

2. (*Rothpletz*) That No. 5 of his section, the Capitol Creek shale (p. 281), is a bed of shale interbedded in the "Helena" limestone of Walcott.

2. (*Walcott*) The Rothpletz shale No. 5 is the Middle Cambrian, Park shale of Weed (p. 281) that carries a typical Middle Cambrian fauna at Helena and vicinity.

3. (*Rothpletz*) That No. 4 of his section (p. 281), the limestone beneath the Capitol Creek shale, is the lower portion of the Helena limestone of Walcott.

3. (*Walcott*) The Rothpletz limestone No. 4 is the Middle Cambrian, Meagher limestone of Weed (p. 281) which has been recognized around the Big Belt and Little Belt Mountains.

4. (*Rothpletz*) That No. 3 of his section (p. 281), the shales beneath the lower limestone, is the pre-Cambrian Empire shale of Walcott.

4. (*Walcott*) The Rothpletz shale No. 3 is the Middle Cambrian, Wolsey shale of Weed (p. 281) which carries a typical Middle Cambrian fauna.

5. (*Rothpletz*) That No. 2 of his section (p. 281), the brownish weathering quartzite beneath the Empire shale of Conclusion *4*, may be the upper part of No. 1 (=pre-Cambrian Spokane shale of Walcott). He qualifies this by saying, "A comparison for No. 2 with the Lower Cambrian Flathead quartzite would be nearer."

5. (*Walcott*) The Rothpletz quartzite No. 2 is the Middle Cambrian basal Flathead quartzite of Weed (p. 281) that is superjacent to the Belt formations about Helena, the Spokane Hills, and around the Big Belt, Little Belt and in the Big Snowy Mountains.

6. (*Rothpletz*) That No. 1 of his section (p. 281), the green and gray argillaceous shale, occupies the position of the Spokane shale of Walcott.

6. (*Walcott*) The Rothpletz shales No. 1 are the shales above the pre-Cambrian, Helena limestone and beneath the Cambrian Flathead quartzite, and occupy the position of the Marsh shale as it occurs elsewhere.

7. (*Rothpletz*) That the fauna of the Capitol Creek shale No. 5 of his section is of Lower Cambrian age (p. 291).

7. (*Walcott*) The Rothpletz "*Lower*" Cambrian fauna of his shale No. 5 (=Middle Cambrian Park shale of Weed) is the usual Middle Cambrian fauna characteristic of the Park shale on Mount Helena and southeast of the city of Helena (pp. 268, 292).

8. (*Rothpletz*) That having found a "*Lower*" Cambrian fauna in the shale of No. 5 and concluded that this shale was interbedded between 4 and 6 in the pre-Cambrian, Helena limestone of Walcott, it followed that the Helena limestone was of Cambrian age and along with it the conformably subjacent Empire and Spokane shales and presumably all of the Belt formations of Walcott.

8. (*Walcott*) The Rothpletz identification of the Middle Cambrian Pilgrim and Meagher limestones on Mount Helena and southeast of the city of Helena as the pre-Cambrian Helena limestone of Walcott is incorrect, and further it was the main source of the Rothpletz series of errors in connection with the stratigraphic position and age of the Cambrian and pre-Cambrian formations about the city of Helena.

9. (*Rothpletz*) That not having observed an unconformity at Helena beneath the Cambrian as stated by Walcott, such an unconformity probably did not exist.

9. (*Walcott*) The Rothpletz failure to find any evidence of an unconformity at the base of the Cambrian is most natural as he unknowingly identified the Cambrian limestones as the pre-Cambrian Helena limestone and hence did not recognize and probably did not see at all the Helena limestone which is beneath the unconformity.

10. (*Rothpletz*) That in the absence of an unconformity at the base of the Cambrian (at Helena) and the absence of a distinctive pre-Cambrian fauna all of the so-called North American pre-Cambrian sedimentary formations of the Belt series were probably of Cambrian age.

10. (*Walcott*) The evidence both direct and by deduction sustains the view of a long pre-Cambrian interval of erosion resulting in a marked unconformity. The Algonkian in America consists of a great series of epicontinental formations between the Archean and Cambrian. The Rothpletz view of considering all of the pre-Cambrian sedimentary formations of North America corresponding to the Belt series as of probable Cambrian age is without evidence to support it.

Some general conclusions.—(*Walcott*) It is unfortunate that my respected colleague in preparing his memoir should have failed to fully examine literature on the subject available in the libraries of Munich or to secure fuller information and maps from official sources in this country. A request on his part for information as to what had been published on the Helena district, sent either to the Director of the U. S. Geological Survey or to me in the winter of 1913-1914, or while he was at my camp on Burgess Pass, British Columbia, would have informed him of the geologic map of the Helena District and descriptions contained in Bulletin 527 of the Survey.

In final conclusion let me add that there is a great amount of work yet to be done on the pre-Cambrian sedimentary rocks of the North American continent. Those of the Lake Superior region are largely well mapped and described, as are portions of those of the Appalachian region, central Texas, southwestern Colorado, and northern Arizona, but large areas in Montana and northward in Alberta and British Columbia remain to be studied, mapped, and described. New discoveries will be made and older views changed, but in the light of our present information I think we are forced to accept the evidence that the Algonkian formations of North America are of pre-Cambian age; of continental origin, and formed of terrigenous deposits that accumulated on river flood-plains and other favorable areas, or deposited in epicontinental, brackish-water seas or fresh-water lakes that filled depressions within the area of the Cordilleran and Appalachian geosynclines [1] and the Lake Superior region.

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[1] Problems of Geology, Yale Univ. Press, 1914, Chap. 4: The Cambrian and its Problems, p. 165.

DESCRIPTION OF PLATE 44

PAGE

Lingulella helena (Walcott) ....

FIG. 1. (× 5.) Exterior of a slightly distorted ventral valve from locality **302s**, Middle Cambrian: Park (siliceous) shale, 1.5 miles southwest of Helena, Lewis and Clark County, Montana. U. S. National Museum, Catalogue No. 27320a.

2. (× 5.) Cast of the interior of a dorsal valve showing area, from the locality represented by fig. 1, U. S. National Museum, Catalogue No. 27320d.

Figs. 1 and 2 are the originals of figs. 3 and 3c of Plate 24, Monogr. 51, U. S. Geol. Survey, 1912.

3 and 4. (× 5.) Somewhat distorted dorsal valves associated with typical ventral and dorsal valves such as those represented by figs. 1 and 2. U. S. National Museum, Catalogue Nos. 62545 and 62546.

The specimens represented by figs. 3 and 4 are from the same shale and locality as those represented by figs. 1 and 2.

5. (× 6.) A small distorted dorsal valve. U. S. National Museum, Catalogue No. 62547.

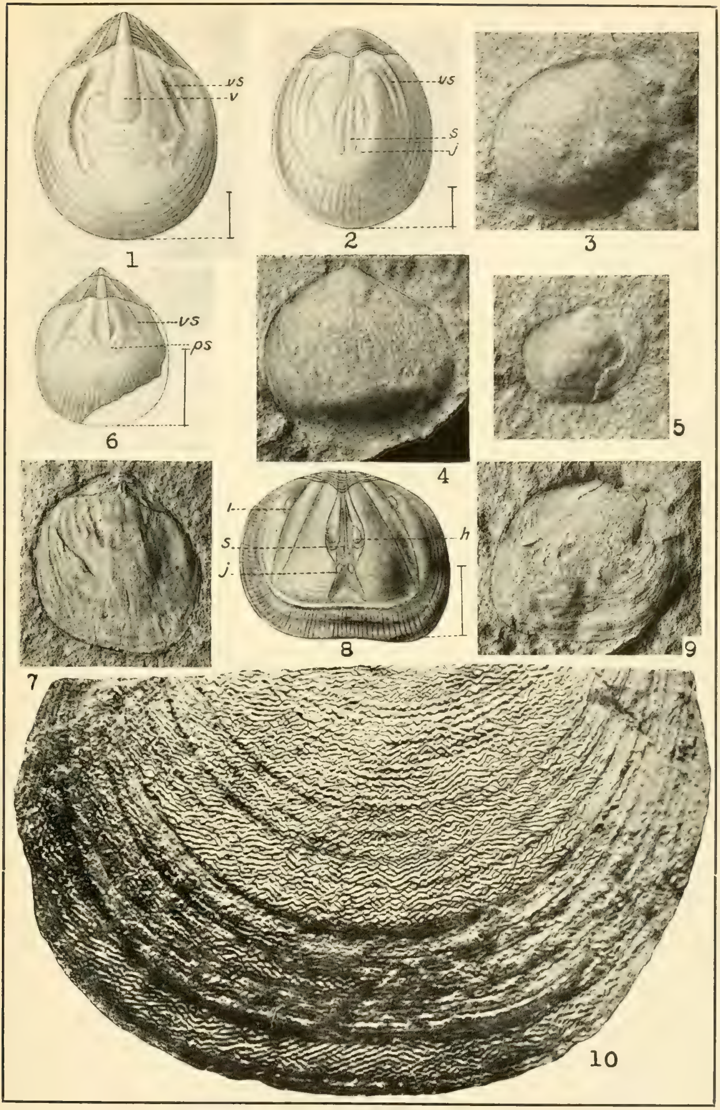
The specimen represented by fig. 5 is from locality **4u,** Middle Cambrian: Park shale, on the northwest side of Grizzly Gulch about one-half mile southwest of the city of Helena, Montana.

Obolus (*Westonia*) *ella* (Hall and Whitfield) ....

FIG. 6. (× 2.) Impression of the interior of a ventral valve from locality **302s,** Middle Cambrian Park shale in Grizzly Gulch, southwest of Helena, Montana. U. S. National Museum, Catalogue No. 51686a. Specimen figured by Walcott, fig. 1*g*, Plate 47, Monogr. 51, U. S. Geol. Survey, 1912.

7. (× 2.) Slightly compressed and distorted ventral valve. U. S. National Museum, Catalogue No. 62548.

8. (× 2.) Impression of the interior of a slightly distorted dorsal valve from the same locality as specimen represented by fig. 6, showing the characteristic muscular impressions. U. S. National Museum, Catalogue No. 51686b. Specimen figured by Walcott, fig. 1*k*, Plate 47, Monogr. 51, U. S. Geol. Survey, 1912.



BRACHIOPODA FROM PARK SHALE OF MIDDLE CAMBRIAN

Obolus (*Westonia*) *ella* (Hall and Whitfield)—Continued. PAGE

FIG. 9. (× 2.) A distorted dorsal valve associated with the specimen represented by fig. 7, U. S. National Museum, Catalogue No. 62549.

Figs. 7, 8 and 9 are from the Middle Cambrian: (**302s**) Park shale, on northwest side of Grizzly Gulch, about 1.5 miles southwest of the city of Helena.

10. (× 10.) Enlargement by photography of the surface of a specimen preserved in a shale where the exterior surface does not adhere to the matrix. Where the surface clings to the matrix, the specimens have the appearance of those illustrated by figs. 7 and 9.

Fig. 10 is of a specimen from locality **4g**, Middle Cambrian: about 325 feet (99.1 m.) above the base of the Cambrian, in the Flathead shales of Peale, 1 mile (1.6 km.) north of the junction of East and West Gallatin Rivers, Gallatin County, Montana.

U. S. National Museum, Catalogue No. 51685c. Specimen figured by Walcott, fig. 1 *o*, Plate 47, Monogr. 51, U. S. Geol. Surv., 1912.

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

III

No. 5. CAMBRIAN TRILOBITES

(With Plates 45 to 67)

BY
CHARLES D. WALCOTT

(Publication 2420)

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No. 5.—CAMBRIAN TRILOBITES

By CHARLES D. WALCOTT

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CONTENTS

PLATES

INTRODUCTION

This is the third of a series of papers on Cambrian Geology and Paleontology that bears the title "Cambrian Trilobites." Reference to earlier papers may be found on page 160 of this volume.

The present paper deals principally with the species of the genera *Corynexochus, Dolichometopus, Bathyuriscus, Asaphiscus,* and *Blountia,* and more incidentally with species of the genera *Illænurus, Lisania, Marjumia, Maryvillia, Mesonacis, Ogygopsis,* and *Orria.*

The genus *Corynexochus* and its subgenus *Bonnia* are of special interest to the geologist, as the geographic distribution of the species *C. senectus* and the two closely related species of *Bonnia*—*C.* (*Bonnia*) *parvulus* and *C.* (*Bonnia*) *fieldensis*—afford a means of

comparing the Lower Cambrian fauna of the St. Lawrence-Newfoundland area with that of the Lower Cambrian Mount Whyte formation of the Canadian Rocky Mountain region adjoining the Canadian Pacific Railway. In these widely separated areas we find *Corynexochus senectus* and the closely related forms of *Bonnia*—*C.* (*B.*) *parvulus* and *C.* (*B.*) *fieldensis*—associated[1] with typical forms of the Mesonacidæ, two of which are illustrated on plate 45 of this paper. I hope in a future paper to consider this subject both from its stratigraphic and paleontologic aspects.

The genus *Corynexochus* may have been the primitive type from which the more highly developed genera *Bathyuriscus* and *Dolichometopus* descended, or it may be that they had a common ancestor in early Lower Cambrian time. My first conclusion was to refer *Bathyuriscus* to the Bathyuridæ, but as the relations with *Corynexochus* became more apparent it seemed more in accord with what appeared to be the natural evolution of the Corynexochidæ to consider *Bathyuriscus* as linked with *Corynexochus* in a line of descent that passed into *Dolichometopus*. This would place the Bathyuridæ as an offshoot from some *Bathyuriscus*-like ancestor in late Cambrian or early post-Cambrian time.

The Middle Cambrian genera *Olenoides, Neolenus,* and *Oryctocephalus* have in the glabella, palpebral (ocular) ridge and pygidium characters that serve to bring the family Oryctocephalidæ Beecher close to the Corynexochidæ, and it is possible that *Olenoides* and *Neolenus* should be placed under the latter family or a subfamily of it.

I now have a considerable series of undescribed Cambrian trilobites that have been grouped under genera and species, and of which figures have been made for illustration. These will be studied and descriptions prepared for publication as opportunity permits.

DESCRIPTIONS OF GENERA AND SPECIES

Family Corynexochidæ Angelin

Corynexochidæ Angelin [1852] 1854, [1878] Pal. Scandinavica, 2d. ed., 1854, p. 59. (Names family under genus *Corynexochus* but does not describe it.)

Opisthoparia with cephalon and pygidium subequal in size or with pygidium smaller than the cephalon. Glabella usually expanded anteriorly and with only narrow limb and border in front. Eyes of medium to large size, with strong palpebral lobe and with palpebral

[1] See lists accompanying description of *Corynexochus senectus* (pp. 321-322).

(ocular) ridge crossing fixed cheek. Thorax with 7 to 11 segments; pleural furrows broad and usually straight. Pygidium more or less strongly ribbed. Surface of test apparently punctate and with irregular, inosculating, fine, sharp ridges which may be smooth or broken up into granulated ridges.

The typical genus of this family is *Corynexochus,* and of the subfamily Dolichometopinæ the typical genera are *Bathyuriscus* and *Dolichometopus. Corynexochus* and *Bathyuriscus* originate in the upper portion of the Lower Cambrian. *Corynexochus* has four Lower and five Middle Cambrian species. Its subgenus *Bonnia* is confined to the Lower Cambrian, as far as known. *Dolichometopus* with its large cephalon and pygidium has 13 Middle Cambrian species. *Bathyuriscus* has two species in the upper portion of the Lower Cambrian, *B. batis* and *B. primus,* and twenty species in the Middle Cambrian. The line of descent indicated in Cambrian time is from a *Corynexochus*-like ancestor to *Bathyuriscus* and *Dolichometopus.*

The pleural lobes of the pygidium of young specimens of *Dolichometopus* are ribbed as in *Corynexochus,* and thus suggest that the genus descended from a *Corynexochus*-like ancestor. The glabella and eyes of some forms of *Dolichometopus* approach some species of *Olenoides.*

The thoracic pleural segments of *Corynexochus* are often similar in character to those of *Dorypyge,* and there is also a resemblance in the glabella of some of the species of the subgenus *Bonnia.*

Genus *Corynexochus* Angelin.—Cephalon larger than the pygidium. Glabella expanded anteriorly and with glabellar furrows.

Subgenus *Bonnia.*—Glabella with sides subparallel and with slight traces of glabellar furrows.

Subfamily Dolichometopinæ.—Corynexochidæ with glabella expanded in front or with subparallel sides.

Genus *Dolichometopus* Angelin.—Cephalon and pygidium subequal in size. Glabella nearly smooth.

Genus *Bathyuriscus* Meek.—Cephalon usually larger than pygidium. Glabella with distinct furrows.

Genus CORYNEXOCHUS Angelin

Corynexochus ANGELIN, [1852] 1854, [1878] Pal. Scandinavica, 2d ed., 1854, p. 59. (Latin diagnosis of genus. First species, *C. spinulosus,* p. 59, pl. 33, figs. 9, 9*a,* 11?.)

Corynexochus ZITTEL, 1885, Handbuch d. Pal., Vol. 2, Munich, p. 602. (Brief diagnosis of genus.)

Karlia WALCOTT, 1889, Proc. U. S. Nat. Mus. for 1888, Vol. 11, p. 444. (Genus described.)

Corynexochus MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 47. (Mentions genus and describes new species, *C. romingeri*.)

Corynexochus LINDSTRÖM, 1901, Kongl. Sven. Vet.-Akad. Handl., Vol. 34, No. 8, p. 22. (Lists genus in connection with development of "facial ridge.")

Corynexochus GRÖNWALL, 1902, Danmarks Geol. Unders. Vol. 2, No. 13, Bornholms Paradoxideslag, p. 136. (Names *C. spinulosus* Angelin as the type and describes and illustrates the cranidium and associated pygidium; also describes and illustrates a new species, *C. bornholmiensis*.)

Karlia WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, No. 3, p. 223. (Description reprinted from 1889 and type species illustrated.)

Description.—General form of dorsal shield longitudinally oval, moderately convex. Cephalon transversely semicircular with genal angles rounded or extended backward in sharp spines; marginal border narrow, rounded or slightly flattened; in front widening toward the genal angles; posterior margin and occipital ring defined by a well-marked furrow. The facial sutures cut the anterior margin so as to leave a small antero-lateral space next to the glabella and curve inward to the base of the eyes, over which they arch; back of the eyes they extend obliquely outward and backward nearly to the genal angles.

Glabella elongate, expanded anteriorly and contracting gradually in width from the little pits in which the dorsal furrows terminate anteriorly; marked in varying degrees of strength by two or three pairs of rather short lateral furrows, the posterior two pairs of which, if present, slope obliquely inward and backward.

Occipital ring clearly defined, broadly rounded and low, or narrow and high, with or without a median spine. On *Corynexochus senectus* it is without a spine (pl. 56, fig. 1). *Corynexochus spinulosus* has a small node at the center (pl. 55, fig. 1), and *Corynexochus bubaris* has a rather strong occipital spine (pl. 56, fig. 3*c*). Occipital furrow varying in width and depth, but distinct and clear in all species.

Fixed cheeks moderately convex, with large, roughly triangular postero-lateral limbs, narrow to medium width of central section, and small antero-lateral limbs; palpebral lobes one-sixth to one-fourth the length of the cranidium with a narrow palpebral ridge coming around the eye and extending obliquely inward and forward across the fixed cheek to the dorsal furrow beside the glabella. Free cheeks narrow, usually with a genal spine, but may be rounded posteriorly as in *C. minor* (pl. 55, fig. 6).

Thorax with 7 (*C. minor*) or 8 (*C. bubaris*) segments; strongly trilobed and moderately convex; pleural lobes flattened, with the segments terminating rather abruptly in blunt points (*C. minor*) or rounded (*C. stephenensis*); pleural furrow broad, straight with narrow margins from dorsal furrow to where it abruptly narrows near the termination of the segment.

Pygidium semicircular in outline, moderately convex, strongly lobed, and with a narrow, well-defined, slightly rounded border that has two or more short, sharp marginal spines projecting from it; axial lobe with 3 to 5 rings and a terminal section; pleural lobes marked by 3 to 5 flat segments that are separated by shallow furrows, and with only the faintest trace of pleural furrows.

Hypostoma (pl. 55, fig. 6*a*) much like that of *Bathyuriscus*.

Surface of test punctate in varying degree owing to size and number of punctæ; it is often marked by fine, irregular, inosculating ridges that may be sharp and unbroken or broader and carrying small tubercles so as to give a granular appearance to the surface (*C. bubaris*, p. 314).

Dimensions.—Most of the species are small. *Corynexochus bubaris*, the largest, reaches 25 to 30 mm. in length, and *C. minor* rarely more than 5 mm.

Genotype.—*Corynexochus spinulosus* Angelin [Pal. Scandinavica, 1854, p. 59].

Stratigraphic range.—*Corynexochus senectus*, *C. brennus*, *C. bubaris*, *C. clavatus*, and *C. capito* occur in the upper portion of the Lower Cambrian on the eastern side of the North American Continent. From the Middle Cambrian, *C. spinulosus*, *C. bornholmiensis*, *C. delagei* from northwestern Europe, *C. minor* from eastern Newfoundland, and *C. stephenensis* from eastern British Columbia and southern Idaho.

Geographic distribution.—This has been outlined above under Stratigraphic Range.

Observations.—It was not until Grönwall published figures of *Corynexochus spinulosus* in 1902 that the type of genus was made known so that it could be compared with other forms. Angelin's figures are too diagrammatic, as may be seen by comparing them with Grönwall's. The cranidium of *Corynexochus* is somewhat similar to that of *Dolichometopus*, but a comparison of the figures of the types of the two species (compare figs. 3, 4, pl. 50, with figs. 1, 1*a*, pl. 55) shows marked differences. *Corynexochus* also differs from *Bathyuriscus* (pl. 46, figs. 2, 2*a-b*) in its glabella, fixed cheeks, thorax, etc.

Grönwall, in writing of *Corynexochus,* stated that the genus was " founded by Angelin on two species: *C. spinulosus* from the Andrarum limestone, of which the head is known and the pygidium is cited with ?, and *C. umbonatus* from the *Orthoceras* limestone, of which only the pygidium is known. The former pygidium is of a type which can hardly belong to the head figured, hence it is best to follow Matthew's example, and consider the head of *C. spinulosus* as a type for the genus, which doubtless should be referred to the Olenidæ, and placed near *Dolichometopus*." [1] The second species, *C. umbonatus,* clearly does not belong under *Corynexochus.*

Through the courtesy of Professor Gerhard Holm, of Stockholm, and the kindness of Dr. Karl Grönwall, I have received wax impressions of Angelin's type specimens of *Corynexochus spinulosus* on which he based his description and illustrations. By comparison of these with the cranidia of *C. minor* (pl. 55, figs. 6, *6a-d*) it appears that *C. minor* is a representative form of the genus. It has the same type of cranidium (compare figs. 1 and *6b*, pl. 55), and the associated pygidium is similar. This indicates that the dorsal shield of *C. spinulosus* was similar in form to that of *C. minor. Corynexochus senectus* (pl. 55, figs. 7, *7a*; pl. 56, figs. 1, *1a-g*) has a less expanded glabella, but with that exception it is as far as known congeneric with *C. spinulosus.* For the species having a glabella with subparallel sides I have proposed the subgenus *Bonnia.*

Species of Corynexochus.—The species now referred to *Corynexochus* are:

Corynexochus bornholmiensis Grönwall (pl. 55, fig. 2), Middle Cambrian.
Corynexochus brennus Walcott (pl. 57, fig. 3), Lower Cambrian.
Corynexochus bubaris Walcott (pl. 56, fig. 2), Lower Cambrian.
Corynexochus capito Walcott (pl. 57, fig. 2), Lower Cambrian.
Corynexochus clavatus (Walcott) (pl. 55, fig. 4), Lower Cambrian.
Corynexochus delagei Miquel (pl. 55, fig. 3), Middle Cambrian.
Corynexochus minor Walcott (pl. 55, fig. 6), Middle Cambrian.
Corynexochus senectus (Billings) (pl. 56, fig. 1), Lower Cambrian.
Corynexochus spinulosus Angelin (pl. 55, fig. 1), Middle Cambrian.
Corynexochus stephenensis (Walcott) (pl. 55, fig. 5) Middle Cambrian.

Generic reference of species heretofore placed under Corynexochus and now referred as follows:

Corynexochus romingeri Matthew = *Corynexochus stephenensis* (Walcott).
Corynexochus ? umbonatus Angelin = *Aeglina.*

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[1] Bornholms Paradoxideslag, Danmarks Geol. Undersøgelse, Vol. 2, No. 13, 1902, p. 136.

CORYNEXOCHUS BORNHOLMIENSIS Grönwall

Plate 55, figs. 2, *2a-b*

Corynexochus bornholmiensis GRÖNWALL, 1902, Danmarks Geol. Unders., Vol. 2, No. 13, Bornholms Paradoxideslag, p. 137, pl. 4, figs. *1a, 1b,* 2; p. 217. (Described and figured as a new species.)

Original description (*in substance*).—" Only the central part of the head and the tail are known. Head anteriorly without a sharp margin, curved, with a considerably expanded front. Dorsal grooves diverge from the back toward the front, and end in a small pit; they are somewhat depressed posteriorly so that the front is club-formed or somewhat pear-shaped. The front is anteriorly broadly rounded, and in this place twice as broad as at the occipital ring. There are either no lateral grooves, or two to three pairs, very weak and short. The branches of the facial suture cut off a small part of the anterior border outside of the front, and diverge strongly, going in an almost straight line to the posterior margin of the head, whereby the fixed cheeks attain an almost triangular periphery. The eyes are crescentic in shape, medium large, occupying the foremost half of the distance from the front to the posterior margin of the head. The cheeks are pretty strongly curved, but not so smooth as the front. The occipital groove is distinct, broadest along the outside. The occipital ring narrow, with a little, short spine.

" The pygidial shield is almost flat, about semicircular in form, and retains its border. The median lobe is distinctly delineated, narrow, and almost the length of the entire pygidium; it has 4 or 5 segments, which in the flat lateral lobes appear as indistinct ribs alternating with the rings on the median lobe.

" The cranidium is flat, with fine, depressed points.

" Dimensions:

Length of head	5	mm.
Width of head	6	"
Width of glabella anteriorly	3.5	"
Width of occipital ring	1.5	"

" Two specimens of the head and two of the tail are in the Mineralogical Museum, associated with *Paradoxides tessini* and *Agnostus parvifrons* from Borregaard, Øle Aa. In the Museum of Stockholm there are 13 specimens of the head and six of the tail, which the writer examined through the courtesy of Professor Lindström. All are preserved in limestone, labeled Bornholm, which contains only very little of other petrifactions. One specimen is associated with *Agnostus nathorsti, Hyolithes socialis, Acrotreta*

socialis, and *Raphistoma ? bröggeri.* These fossils show that the species is from about the Andrarum limestone horizon.

Formation and locality.—Middle Cambrian: Limestone at Borregaard, Bornholm Island, Denmark.

CORYNEXOCHUS BRENNUS, new species

Plate 57, figs. 3, *3a-b*

This species came from a boulder of light gray arenaceous limestone derived from the conglomerate at Bic Harbor. It differs from *C. senectus* in having a beautifully ornamented outer surface and a narrow, sharply elevated occipital ring. The surface of the glabella has fine, sharp, irregular ridges arranged in a roughly concentric manner about its longitudinal center, and is very similar to the surface of *Corynexochus* (*Bonnia*) *parvulus* (pl. 64, fig. 6). The test between the fine ridges is minutely punctate. The associated pygidia are more transverse and smoother than the pygidium of *C. senectus* or *C. bubaris.* The largest cranidium has a length of 7 mm.

A single pygidium from (locality 2r) 2 miles west of the railway station at Bic appears to belong to this species. It was associated in the same rock with fragments of *Callavia bicensis* and *Zacanthoides.*

Formation and locality.—Lower Cambrian: (2 o) Limestone boulders in conglomerate on shore at east entrance to harbor at Bic; also doubtfully (2r) limestone boulders in a cut on the Intercolonial Railway, 2 miles (3.2 km.) west of Bic railway station, both in Rimouski County, Quebec, Canada.

CORYNEXOCHUS BUBARIS, new species

Plate 56, figs. 2, *2a-b*, 3, *3a-f*

This species differs from *C. senectus* in having a strongly granulated surface, sharply elevated occipital ring with a small, sharp median spine, and more strongly ribbed pygidium. The granulated surface is formed by little nodes that appear to rise from irregular ridges, the interspaces of which are finely punctate; when the thin exterior layer of the test is rubbed off or exfoliated the inner layer appears to be punctate. An enrolled specimen shows eight segments, and the pygidium three rings and a terminal section.

The granulated surface of this species is of the same character as that of *Corynexochus* (*Bonnia*) *busa* Walcott (pl. 60, fig. *3c*).

The pygidium not only has a minute fringing spine at the end of the anterior border of the first anchylosed segment, but also similar minute spines opposite the second and third segments. This character

brings the pygidium near to those of *Eurycare, Peltura* and other genera having fringing spines on the border of the pygidium.

The type specimens of this species are from a limestone boulder in the Bic conglomerate and preserve the exterior surface, while those identified with it from Vermont are in a shaly sandstone, and those from Pennsylvania are in an arenaceous limestone. The latter sometimes show traces of the granular surface so beautifully preserved in the limestone matrix.

Specimens from the limestone near Emigsville, Pennsylvania (locality 49w), show a granulated surface and an occipital spine characteristic of the species.

Formation and locality.—Lower Cambrian: (2 o) Limestone boulders in conglomerate on shore at east entrance to harbor at Bic, Rimouski County, Quebec, Canada.

(49) Sandstone on Codorus Creek 0.125 mile (0.2 km.) below Meyer's mill, near Emigsville; (49a) sandstone on the Liverpool road, south of the schoolhouse, 3 miles (4.8 km.) northwest of York; and (49w) limestone in railroad cut, 0.25 mile (0.4 km.) south of Emigsville railroad station; all three localities in York County, Pennsylvania.

CORYNEXOCHUS CAPITO, new species

Plate 57, figs. 2, *2a-e*

Protypus senectus Billings, WALCOTT, 1886, Bull. U. S. Geol. Surv., Vol. 30, p. 213, pl. 31, figs. 2, *2a-c*. (Prints original description with comments and illustrates two cranidia and one associated pygidium from Vermont.)

Protypus senectus LESLEY, 1889, Geol. Surv., Pa., Rept. P. 4, p. 784, 2 text figs. only. (Compares with Angelin's *Corynexochus spinulosus* and reproduces Walcott's figures of 1886.)

Protypus senectus WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Surv., p. 655, pl. 98, figs. 7, *7a-c*. (Reproduces figures of 1886.)

This form was formerly identified as the species *senectus*, but with the specimens now available for study from Vermont and York (Pennsylvania) it appears that a distinct species is present that is neither *C. senectus* nor *C. bubaris*. The normal glabella is broader than in other species and almost devoid of side furrows. Anterior border narrow and close to the glabella; palpebral lobes small and narrow; occipital ring narrow and high at the posterior center but without a spine as far as can be determined.

The associated pygidia are larger and more rugged in appearance than those associated with *C. senectus*. There is a small, short,

anterior marginal spine as in the latter species. Axial lobe with three or four rings and a terminal section; pleural lobes with three broad flat segments separated by narrow shallow grooves.

All the specimens are from arenaceous shale and decomposed arenaceous limestone.

Formation and locality.—Lower Cambrian: (25) Shaly sandstone just above Parkers quarry, Georgia, Franklin County, Vermont.

Also (48b) York formation; roadside, north of Highland Park, York, York County, Pennsylvania.

CORYNEXOCHUS CLAVATUS (Walcott)

Plate 55, figs. 4, 4*a-b*

Ptychoparia ? (Subgenus ?) *clavata* WALCOTT, 1887, American Jour. Sci., 3d ser., Vol. 34, p. 198, pl. 1, fig. 3. (Note on the species and illustration of a cranidium.)

Protypus ? clavatus WALCOTT, 1891, Tenth Ann. Rept. U. S. Geol. Surv., p. 656, pl. 98, fig. 4. (Republishes note and illustration of 1887.)

These minute cranidia, the largest 2.5 mm. in length, have the characters of the typical form of *Corynexochus* as illustrated by figure 1, plate 55, of this paper. The American Lower Cambrian species differs from *C. spinulosus* of the Middle Cambrian of Sweden in having a broader fixed cheek in front of the ocular ridge and a proportionally greater widening of the anterior half of the glabella. The glabella has four pairs of furrows, the posterior pair united across the glabella by a short transverse furrow. The palpebral lobes are of medium size and quite prominent. Anteriorly they unite with the ridge which extends across the fixed cheeks to the dorsal furrow beside the glabella.

Surface marked by irregular exceedingly fine elevated lines or sharp ridges arranged concentrically about the anterior portion of the glabella and more or less transversely across the posterior portion. These lines can only be seen by the aid of a rather strong lens.

Corynexochus clavatus is the oldest known species of the genus. It is associated with a large and typical Lower Cambrian fauna at several localities. The associated fauna includes (locality numbers in parentheses):

Micromitra (*Iphidella*) *pannula* (White) (38*a*)
Obolus prindlei (Walcott) (38*a*)
Lingulella granvillensis Walcott (38*a*)
Lingulella sp. (38*a*)
Botsfordia cœlata (Hall) (33, 38*a*, 39, 43*a*)
Yorkia ? washingtonensis Walcott (38*a*)
Acrotreta emmonsi Walcott (38*a*)

Acrotreta sagittalis taconica (Walcott) (33, 38*a*, 39, 43*a*)
Nisusia festinata (Billings) (38*a*)
Billingsella salemensis (Walcott) (33)
Archæocyathus dwighti Walcott (33, 39)
Protospongia sp. (38*a*, 43*a*)
Platyceras primævum Billings (38*a*)
Hyolithellus micans (Billings) (33, 38*a*)
Hyolithellus micans rugosa Walcott (38*a*)
Hyolithes americanus Billings (33, 38*a*)
Hyolithes communis Billings (33)
Hyolithes impar Ford (33, 38*a*, 43*a*)
Stenotheca elongata Walcott (33)
Stenotheca rugosa (Hall) (33)
Agnostus desideratus Walcott (43*a*)
Agnostus sp. (38*a*)
Eodiscus connexus Walcott (38*a*, 43*a*)
Eodiscus speciosus Ford (33, 38*a*, 39, 43*a*)
Goniodiscus lobatus (Hall) (33, 38*a*, 43*a*)
Elliptocephala asaphoides Emmons (33, 38*a*)
Ptychoparia cf. *adamsi* (Billings) (33, 38*a*, 43*a*)
Ptychoparia fitchi Walcott (38*a*)
Ptychoparia sp. (38a)
Zacanthoides eatoni Walcott (33, 38*a*, 43*a*)
Olenoides fordi Walcott (38*a*)
Solenopleura tumida Walcott (33)

Formation and locality.—Lower Cambrian: (43a) Limestone 1 mile (1.6 km.) east-northeast of Salem, Cambridge quadrangle (U. S. G. S.); (33) limestone on the roadside near Rock Hill Schoolhouse, near North Greenwich, about 5 miles (8 km.) north-northeast of Greenwich, Cambridge quadrangle (U. S. G. S.); (38a) limestone 2 miles (3.2 km.) south of North Granville, on the road which turns south from the road running between that village and Truthville, 4 miles (6.4 km.) west-northwest of Granville, Fort Ann quadrangle (U. S. G. S.); and (39) limestone south of the Delaware and Hudson Railroad track, on the road running south-southwest from Low Hampton, about 5 miles (8 km.) east-northeast of Whitehall, Whitehall quadrangle (U. S. G. S.), all in Washington County, New York.

CORYNEXOCHUS DELAGEI Miquel

Plate 55, figs. 3, 3*a*

Corynexochus delagei Miquel, 1905, Bull. Soc. géol. France, 4th ser., Vol. 5, p. 481, pl. 15, figs. 4, 4*a-b*. (Describes and illustrates cranidium and pygidium.)

Original description.—"The roughly triangular head, with a rounded top, in the majority of specimens is more crushed, more

semicircular in the large forms, which are perhaps accidentally depressed by compression.

"The glabella has, much more, even, than in all the other species of the genus, the *clavate* form described by authors. Very narrow in the lower part and often compressed at the base, it expands abruptly, toward the middle of its height, into a regular oval, sometimes a complete circle. It has its dorsal furrows accentuated and stands out in relief above them; there is no trace of lateral furrows; the occipital furrow is hardly distinct; but below it, however, the occipital ring appears, very narrow, convex, and rounded, and terminates in a spine quite apparent to the naked eye on certain specimens.

"The facial suture becomes detached at two-thirds the height of the glabella, at the point where the convexity of the latter is most marked, and descends toward the base by an almost straight line, sometimes slightly convex, so as to give to the fixed cheeks a very narrow, triangular form. The very small eyes are scarcely visible. The free cheek is always lacking. Thorax unknown.

"The pygidium has the form of a semicircle, generally a little depressed; the axis, much in relief, well marked, is narrow and long, without quite reaching the lower margin; we count under the lens five and perhaps six rings. The lateral lobes have the first pleura apparent; the others are more effaced and scarcely visible.

"The test is without punctation.

"*Analogies and differences.*—*Corynexochus delagei* is by far the most specialized of the species which I am describing; it constitutes the only *Corynexochus* known up to the present from the lower beds of the Acadian; it is very clearly distinguished at first sight from *Corynexochus spinulosus* Ang. and from *Corynexochus romingeri* Matt., which belong, in Scania [Skåne] and at Mount Stephen, to the beds with *Paradoxides forchhammeri* Ang. of the upper Acadian. It is nearer *Corynexochus bornholmiensis* Grönw. from the middle Acadian of Borregaard, in the island of Bornholm; but it is distinguished from that by the rounded form of the top of the glabella, by the great convexity of the base of the dorsal furrows, by the complete absence of lateral furrows, and by the effacement of the rings and the pleuræ of the pygidium."

M. J. Miquel very kindly sent me a specimen of the cranidium and one of the pygidium, which are illustrated on plate 55, figures 3, 3*a*. These have a more striking resemblance to the Newfoundland *C. minor* Walcott (pl. 55, fig. 6) than to the geographically nearer *C. spinulosus* Angelin and *C. bornholmiensis* Grönwall.

Formation and locality.—Middle Cambrian: (152d) Calcareous shales; Cambrian section of Coulouma, "Montagne Noire," Hérault, France.

CORYNEXOCHUS MINOR (Walcott)

Plate 55, figs. 6, 6*a-d*

Karlia minor WALCOTT, 1889, Proc. U. S. Nat. Mus. for 1888, Vol. 11, p. 445. (Description of species.)

Karlia minor WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, No. 3, p. 224, pl. 36, figs. 7, 7*a-c*. (Description and illustration of species.)

The description of this species may be found on page 224 of this volume. It is illustrated in this paper in order to afford direct comparison with the other species referred to *Corynexochus.*

Formation and locality.—Middle Cambrian: (1) Manuels formation; Manuels Brook, Conception Bay, Newfoundland.

CORYNEXOCHUS SENECTUS (Billings)

Plate 55, figs. 7, 7*a-c;* plate 56, figs. 1, 1*a-g*

Bathyurus senectus BILLINGS, 1861, Geol. Surv., Canada, Pal. Foss., Vol. I, p. 15, text figs. 19, 20. (Describes and illustrates a cranidium and associated pygidium.)

Bathyurus senectus BILLINGS, 1862, Geol. Vermont, Vol. 2, p. 953, text figs. 359, 360. (Same as above.)

Bathyurus senectus BILLINGS, 1862, Rept. Economic Geol. Vermont, Hager, p. 225, text figs. 359, 360. (Same as above.)

Bathyurus senectus BILLINGS, 1863, Geol. Canada, Geol. Surv., Canada, p. 286, text fig. 298 (fig. only). (Same figures as above.)

Bathyuriscus senectus MATTHEW, 1897, Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, p. 196, pl. 4, fig. 4. (Describes and illustrates the supposed type specimen and refers the species to *Bathyuriscus* and compares it with *Paradoxides.*)

Original description.—"Glabella subcylindrical, clavate, strongly convex, one-fourth wider at the front margin than at the neck segment, sides nearly straight, front obtusely rounded and presenting a strong convex elevation, neck furrow extending all across, three pairs of glabella furrows represented by small but distinct and obtuse indentations in the sides. Fixed cheeks rather strongly convex. Eyes of moderate size, semicircular; a line drawn across the head at about one-third the length of the glabella from behind would pass through them, and they are distant from the side of the glabella about the width of the neck segment. The front of the head is surrounded

by a narrow border which appears to be flat; there appears to be some evidence of a spine on the neck segment.

"The pygidium found in the same fragment of stone with one of the specimens of the glabella of this species is in all general characters that of *Bathyurus*. It is semicircular, convex, axis cylindrical, strongly convex, terminating behind with an abruptly rounded descent, six annulations, the first three or four most strongly defined. The lateral lobes have four segments each, separated by strong rounded furrows; there is a narrow entire margin all round with a distinct groove inside, which appears, however, to be interrupted at the end of the axis.

"The dimensions of the most perfect specimens are as follows:

"Glabella—length, $3\frac{1}{2}$ lines; width at neck segment, $1\frac{1}{2}$ lines, at the front, 2 lines; distance of the eye from the side of the glabella, $1\frac{1}{2}$ lines. The eye appears to be about three-quarters of a line in length.

"Pygidium—length, 3 lines; width at anterior margin, $5\frac{1}{2}$ lines; width of axis, 1 line."

With a number of well-preserved cranidia for study, I find that the occipital segment is elevated slightly toward the center, but that it does not have a spine as suggested by the specimens studied by Billings. Matthew, after studying the material used by Billings, states that he found the surface consisting of anastomosing raised lines on the front half of the glabella; these become broken into a granulated surface on the back of the glabella and cheeks, with finer granulations in the furrows than elsewhere.[1] To his description we may add that the outer surface of the test is punctate and also marked by a fine inosculating network of elevated lines or ridges that are usually obscure and difficult to see even with a strong pocket lens. The granulation mentioned by Matthew shows in the specimens before me either on the summit of the fine ridges or on the cast of the inner surface of the test. Their appearance varies with the amount of rubbing down the test has received or the condition of its preservation in its matrix. The associated hypostomas and pygidia have the same kind of surface as the glabella. From Bonne Bay specimens I find all the associated pygidia have a short spine on each side that is apparently the continuation across the border of the anterior rounded margin of the axial lobe of the pygidium. This same type of pygidium is also associated with *Corynexochus* (*Bonnia*) *parvulus*

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, 1897, p. 197.

(Billings) (pl. 57, fig. 1*c*), as already indicated by Matthew.[1] Many pygidia associated with the cranidia appear to have smooth antero-lateral margins, but usually a trace of the spine may be found by careful removal of the matrix.

The associated pygidium described and figured by Billings has six annulations on the axial lobe and four on the pleural lobes, as in *C. bubaris*. This pygidium may belong with the cranidium, but I find from the Bonne Bay locality that nearly all the pygidia are shorter and have only four to five annulations including the terminal one, and three to four that extend out onto the pleural lobes. The collection from Bonne Bay includes over 100 cranidia, and as many associated pygidia, and there are no other species of this type associated with them. Even *Corynexochus* (*Bonnia*) *parvulus* is absent. The pygidium figured by Billings is much like that of *C. bubaris* (pl 56, fig. 3*d*), which has four annulations in the axial lobe and three on the pleural lobes.

The cranidia are sometimes distorted so as to make elongate and narrow forms; these are illustrated on plate 56, figure 1*c*.

Billings gives l'Anse au Loup on the Straits of Belle Isle as the type locality of the species. Although we have quite large collections from that area, no specimens of the species have been recognized, but at Bonne Bay on the west side of Newfoundland the fragments of the dorsal shield occur in large numbers in association with the following fauna (locality 41 l):

Micromitra (*Paterina*) *labradorica* (Billings)
Botsfordia cœlata (Hall)
Kutorgina cingulata (Billings)
Quebecia n. sp.
Obolella chromatica Billings
Pelagiella primævum Billings
Helcionella rugosa (Hall)
Hyolithes billingsi Walcott
Hyolithes princeps Billings
Hyolithes communis Billings
Hyolithellus micans (Billings)
Salterella pulchella Billings
Salterella rugosa Billings
Olenellus thompsoni crassimarginatus Walcott
Corynexochus senectus (Billings)

The bed above the limestone of 41 l contains fragments of *Olenellus* and numbers of *Salterella*.

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[1] Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, 1897, pl. 4, fig. 5*b*.

At Bic Harbor on the St. Lawrence, *C. senectus* occurs in boulders of light gray limestone associated with fragments of *Olenellus thompsoni* and the following species (locality 2 o):

Micromitra (Paterina) bella (Billings)
Micromitra (Paterina) labradorica (Billings)
Bicia gemma (Billings)
Kutorgina cingulata (Billings)
Obolella crassa (Hall)
Botsfordia cœlata (Hall)
Yorkia wanneri ? Walcott
Nisusia festinata (Billings)
Discinella sp.
Corynexochus (Bonnia) parvulus (Billings)
Corynexochus bubaris Walcott
Zacanthoides spinosus Walcott ?
Olenellus thompsoni Hall

At all three localities *C. senectus* occurs at the upper horizon of the "*Olenellus*" or Lower Cambrian fauna, and in none of them is it known to be immediately succeeded by the "*Paradoxides*" or Middle Cambrian fauna.

The species as identified from locality 61d in British Columbia is represented by large numbers of the cranidium and associated pygydia that vary among themselves very much as the specimens from western Newfoundland. The limestone matrix at the two localities is nearly similar in color and appearance and the associated fauna is very similar. The fauna listed in each instance is from the same layer of limestone containing *Corynexochus senectus*. The horizon of the layer at locality 61d is near the top of the Lower Cambrian Mount Whyte formation, and at locality 41 l in Newfoundland near the summit of the Lower Cambrian (*Olenellus*) series.

The fauna of locality 61d includes:

Acrotreta sagittalis taconica (Walcott)
Nisusia (Jamesella) lowi Walcott
Scenella varians Walcott
Pelagiella sp. undt.
Micromitra (Paterina) labradorica (Billings)
Micromitra (Iphidella) pannula (White)
Corynexochus senectus (Billings)
Agraulos
Zacanthoides
Ptychoparia 2 spp.
Mesonacis gilberti (Meek)

Formation and locality.—Lower Cambrian: Billings gives l'Anse au Loup on the north shore of the Straits of Belle Isle (Labrador) as the type locality.

Collections made for the United States National Museum contain specimens of the species from five localities, as follows:

(41 l) Bonne Bay, east shore of East Arm, west coast of Newfoundland; (2 o) limestone boulders in conglomerate on shore line at east entrance to harbor at Bic, Rimouski County, Quebec, both in Canada.

(49w) Limestone in railroad cut, 0.25 mile (0.4 km.) south of Emigsville, York County, Pennsylvania.

(61d) Mount Whyte formation; southwest slope of Mount Shaffer on Canyon side, on trail to Lake McArthur, 8.5 miles (13.6 km.) south of Hector Station, on Canadian Pacific Railroad, British Columbia, Canada.

Also from (16g): Hard arenaceous shales; Paymaster Mining Camp, 0.25 mile (0.4 km.) west of Esmeralda, Esmeralda County, Nevada.

CORYNEXOCHUS SPINULOSUS Angelin

Plate 55, figs. 1, 1*a-b*

Corynexochus spinulosus Angelin [1852, 1854], 1878, Pal. Scandinavica, 3d ed., Holmiae, p. 59, pl. 33, figs. 9, 11 ?. (Described and figured as a new species.)

Corynexochus spinulosus Grönwall, 1902, Danmarks Geol. Unders., Vol. 2, No. 13, p. 139, pl. 4, figs. 3*a-b*, 4. (Describes and illustrates type specimens.)

Dr. Karl A. Grönwall studied the type specimens of this species which are in the Museum at Stockholm, and in substance wrote the following description:

"Head without margin, anteriorly strongly curved. Length greater than breadth. Front narrow or club-form, delimited with deep, similar dorsal grooves. Lateral grooves, 3 pairs, short and flat; the most posterior pair of grooves are directed backward, nearly enclosing a pair of basal lobes. Eyes small, cheeks narrow, occipital ring moderately broad with a spine. The surface of the cranidium, with densely impressed fine points.

"Considering the pygidial shield, I am in great uncertainty. Angelin illustrates one with spines in margin, which does not show much resemblance to that of *C. bornholmiensis*. Professor Holm told me that he had not succeeded in finding a pygidium for *C. spinulosus* in the Stockholm Museum. Among the heads there was, however, a

small pygidium which appears to me to belong to *C. spinulosus,* and of which for this reason I give a figure (pl. 55, fig. 1*b*) and describe it. Pygidium semicircular in form, with an entire margin. Median lobe about five-sixths of the entire length of the pygidium, curved, with three rings, which on the flat lateral lobes are continued by two broad, indistinct ribs, which alternate with the annular or the rings of the median lobe. Along the posterior margin of the pygidium there is a flat furrow, which indicates a doublure around the pygidium. If this pygidium actually belongs to *C. spinulosus* Angelin, we shall be obliged to change its name, as it refers to a character which does not belong to the species in question. From this description and the figures, the difference between the two closely allied Scandinavian species appears clear enough."

It may be as Grönwall states, that the pygidium illustrated by the diagrammatic figure of Angelin does not belong with the cranidium named *C. spinulosus,* but from our finding somewhat similar spines on the border of the pygidium of *C. bubaris* it is not improbable that Angelin was correct in placing the pygidium he found associated with *C. spinulosus* under the same species.

Formation and locality.—Middle Cambrian: Andrarum limestone at Andrarum, Skåne, Sweden.

CORYNEXOCHUS STEPHENENSIS (Walcott)

Plate 55, figs. 5, 5*a-c*

Menocephalus salteri ? Billings, ROMINGER, 1887, Proc. Acad. Nat. Sci., Philadelphia, Pt. 1, p. 16, pl. 1, fig. 6. (Described and figured.)

Karlia stephenensis WALCOTT, 1889, Proc. U. S. Nat. Mus., Vol. 11, p. 445. (Described.)

Corynexochus roemingeri MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 47. (Calls attention to error in description of 1889, and proposes specific name *Corynexochus roemingeri* for Dr. Rominger's specmiens.

Karlia stephenensis WALCOTT, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 3, fig. 4. (Specimen figured.)

Karlia stephenensis WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, No. 3, p. 224, pl. 36, fig. 8. (Described and figured.)

The size of this species was erroneously stated by me in 1889. Dr. Rominger's type specimen when being studied was placed in a tray with specimens referred to *Protypus,* and the measurements assigned to the species *stephenensis* were taken by error from *Protypus hitchcocki* which happened to be in the tray.

I inserted an illustration of the type of the species *stephenensis* alongside that of *Karlia minor* in my last paper on Cambrian trilo-

bites,[1] and in the text, page 225, had the brief note copied that accompanied the naming of the species in 1889. This illustration of the type and description were inserted to afford the means of comparison with *Karlia minor* just before I was leaving for the field, and I did not look up Dr. G. F. Matthew's paper in which he describes the same form as *Corynexochus roemingeri* Matthew.[2] In this paper Dr. Matthew calls attention to my error in assigning so large a size to the species identified as *Menocephalus salteri ?* by Rominger, and proposes the specific name *Corynexochus roeningeri* for Dr. Rominger's specimens. As it was the species described and illustrated by Dr. Rominger to which the name *Karlia stephenensis* was given, the error in measurement does not cancel that name in favor of the more recent one proposed by Dr. Matthew.

The average length of the dorsal shield of *C. stephenensis* is about 14 mm. There are seven thoracic segments, and three anchylosed segments and a terminal section in the axial lobe of the pygidium. The three axial segments of the pygidium are extended obliquely backward on the pleural lobes as flat, broad segments separated by narrow, shallow furrows.

The specimens of this species occur in a very fine arenaceous shale and none show the original test.

A single cranidium from the Burgess shale at about the same horizon appears to be punctate. This cranidium 1 mm. in length has the glabella very much expanded anteriorly and large, tumid fixed cheeks (pl. 55, fig. 5*a*).

Formation and locality.—Middle Cambrian: (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad; also (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field on the Canadian Pacific Railroad, both in British Columbia, Canada.

BONNIA, new subgenus

Bonnia is proposed as a subgenus of *Corynexochus* with *Bathyurus parvulus* Billings as the genotype.

The subgenus differs from the genus in having a glabella with subparallel sides and only slight traces of glabellar furrows; other parts

[1] Smithsonian Misc. Coll., Vol. 64, 1916, pl. 36, fig. 8.

[2] Trans. Royal Soc. Canada, 2d ser., Vol. 5, 1899, p. 47.

as far as known are essentially the same as *Corynexochus*. The surface of the test of *C.* (*Bonnia*) *parvulus* is punctate and marked by irregular, inosculating, very fine ridges or raised lines that are arranged more or less concentrically about the highest part of the glabella, also about the node on the occipital ring. (See pl. 57, fig. 1; pl. 64, fig. 6.)

The associated pygidia have the anterior border extended into a short spine at the antero-lateral angles and the axial lobe has only two well-defined rings.

Although there are large numbers of the cranidia and pygidia of the species *parvulus*, nothing is known of the thorax. The associated free cheeks have a rather strong genal spine.

Matthew refers the species *parvulus* to *Dorypyge*,[1] but a comparison with the genotype of *Dorypyge* shows that while the glabella is somewhat similar,[2] there are differences in form and surface markings and the associated pygidia are quite unlike. The test of *Dorypyge* is dense and granulated and that of *Bonnia* is punctate and ornamented with elevated lines or fine sharp ridges or granulated. The spines at the end of the anterior border of *Bonnia* can hardly correlate the pygidium with that of *Dorypyge*. For comparison, figures of the genotype of *Dorypyge* are illustrated on plate 64, figures 7, 7*a-c*.

The species now referred to the subgenus *Bonnia* are:

Corynexochus (*Bonnia*) *parvulus* (Billings) (pl. 57, fig. 1), Lower Cambrian.
Corynexochus (*Bonnia*) *busa* Walcott (pl. 60, fig. 3), Lower Cambrian.
Corynexochus (*Bonnia*) *fieldensis* Walcott (pl. 57, fig. 4), Lower Cambrian.

CORYNEXOCHUS (BONNIA) BUSA, new species

Plate 57, fig. 1*a*; plate 60, figs. 3, 3*a-c*

This species is represented by specimens of the cranidium and associated pygidium, the surface characters of which are similar to those of the pygidium. The cranidium is similar in form to that of *C.* (*Bonnia*) *parvulus* except that the fixed cheek is narrower and three pairs of short glabellar furrows are to be seen by the unaided eye.

A small median spine appears to have been broken off of the occipital ring.

The most striking difference is the granulated outer surface of the test on both the glabella, fixed cheeks and associated pygidium; this

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, 1897, p. 197.

[2] See *Dorypyge richthofeni* Dames, figs. 1, 1*a-e*, pl. 8, Research in China, Vol. 3, Cambrian Faunas of China, 1913, Carnegie Inst. of Washington.

granulation is formed on the lines of the fine ridges very much as they occur on *Corynexochus bubaris*.

The associated pygidium is more transverse than that referred to *C.* (*Bonnia*) *parvulus* and also closely granulated.

The largest cranidium has a length of 7 mm.

Formation and locality.—Lower Cambrian: (2 o) Limestone boulders in conglomerate; on shore at east entrance to harbor at Bic, Rimouski County, Quebec, Canada.

CORYNEXOCHUS (BONNIA) FIELDENSIS (Walcott)

Plate 57, figs. 4, 4*a-b*

Protypus fieldensis WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 215. (Listed.)

Corynexochus (*Bonnia*) *fieldensis* differs from *C.* (*Bonnia*) *parvulus* (Billings) in details of cranidium and pygidium. The glabella is proportionally more elongate in specimens embedded in the same character of limestone; the axial lobe of the associated pygidium is less elevated posteriorly.

The differences are slight but persistent, and if occurring in specimens from the same locality and layer of rock would probably receive little attention. With the localities 2,000 miles (3,200 km.) distant from each other, they are given more weight.

The associated pygidium has the same kind of spines at the outer end of the frontal margin, and the rings of the axial lobe and their extension on the pleural lobes are the same except that those of *C.* (*B.*) *parvulus* are more clearly defined.

The occipital ring has a small median spine on the posterior margin very similar to that of *C.* (*B.*) *parvulus*.

Surface of test punctate and only faintly marked by fine, irregular, inosculating ridges.

The average length of the cranidium is about 9 mm.

The separate cranidia and pygidia occur in great numbers in the limestone of the Mount Whyte formation in association with *Mesonacis gilberti* and *O. canadensis*. On Mount Bosworth (locality 35h) the fauna includes:

Nisusia festinata (Billings)
Scenella varians Walcott
Hyolithellus
Ptychoparia
Agraulos
Olenellus canadensis Walcott
Mesonacis gilberti (Meek)
Corynexochus (*Bonnia*) *fieldensis* Walcott

This species is of unusual interest as it is the representative in the Rocky Mountain Cambrian fauna of *C.* (*Bonnia*) *parvulus* of Labrador, which is associated with a Lower Cambrian fauna.

Formation and locality.—Lower Cambrian: (35 l) Mount Whyte formation; at the base of the formation, on the south slope of Ptarmigan Pass, head of Corral Creek, 9 miles (14.4 km.) north-northeast of Laggan, Alberta; (35f) Mount Stephen section of Mount Whyte formation; about 300 feet (95 m.) below the top of the Lower Cambrian, in bluish-black and gray limestone (18 feet = 5.5 m.) forming No. 6 of the formation, and (57i) about 175 feet below the top of the Lower Cambrian in brownish-gray quartzitic sandstone (32 feet) forming 4 of Mount Whyte formation, Mount Stephen section, just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia; and (35h) about 375 feet (114 m.) below the Middle Cambrian in the shales of No. 4 of the Mount Whyte formation,[1] on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen, on the Continental Divide between British Columbia and Alberta, all in Canada.

CORYNEXOCHUS (BONNIA) PARVULUS (Billings)

Plate 57, figs. 1, 1*b-c;* plate 64, fig. 6

Bathyurus parvulus BILLINGS, 1861, Geol. Surv., Canada, Pal. Foss., Vol. 1, p. 16, text fig. 21. (Describes and illustrates a cranidium.)

Bathyurus parvulus BILLINGS, 1862, Geol. Vermont, Vol. 2, p. 953, text fig. 361. (Same as above.)

Bathyurus parvulus BILLINGS, 1862, Rept. Economic Geol. Vermont, Hager, p. 225, text fig. 361. (Same as above.)

Bathyurus parvulus BILLINGS, 1863, Geol. Canada, Geol. Surv., Canada, p. 286, fig. 299 (fig. only.) (Same figure as above.)

Protypus senectus parvulus WALCOTT, 1886, Bull. U. S. Geol. Surv., No. 30, p. 213. (Considers Billings's *Bathyurus parvulus* a variety of *Protypus senectus.*)

Dorypyge parvula MATTHEW, 1897, Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, pp. 187, 197, pl. 4, figs. 5, 5*a*. (Refers species to *Dorypyge* and describes and illustrates cranidium and associated pygidium.)

Compare *Menocephalus salteri* DEVINE, 1863, Canadian Nat. and Geol., Vol. 8, p. 210. (Illustrates and describes this species or one closely related.)

With the exception of the outline of the glabella, the cranidium of this species is not unlike that of *Corynexochus senectus* Billings. The glabella, however, is somewhat like that of *Dorypyge* (pl. 64, figs. 7, 7*a*) and *Pagodia*,[2] but, as we have learned from many examples,

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 214.

[2] Idem, Vol. 57, 1912, pl. 44, figs. 13, 14.

the same type of cranidium may have quite a different thorax and pygidium and belong to distinct genera.

Very perfect specimens of the glabella of *C.* (*Bonnia*) *parvulus* have very faint traces of lateral furrows close to the dorsal furrow, but usually the furrows are not readily determined to be present. The occipital ring rises gently at its posterior center, and a blunt, very small and short spine projects backward from the edge; the base of the spine is surrounded on its sides and front by concentrically arranged, sharp, irregular, fine ridges. The associated free cheek has a relatively strong genal angle.

Corynexochus (*Bonnia*) *parvulus* is associated at locality 4k with *Callavia bicensis* Walcott. At locality 41i, with *Micromitra, Nisusia, Obolella, Hyolithes communis* Billings, *Callavia* sp., and *Olenellus thompsoni* Hall. For the fauna at locality 2 o, see description of *Corynexochus senectus,* p. 319.

Matthew names a variety *angifrons* from a specimen of a cranidium preserved as a cast in sandstone, that is " sensibly narrower " and that has scarcely a trace of glabellar furrows. The locality is unknown. He suggests Vermont. The figures suggest a compressed cranidium of *C.* (*Bonnia*) *parvulus.*

With the poor illustration of *Menocephalus salteri* Devine,[1] it is difficult to make a close comparison between it and *C.* (*Bonnia*) *parvulus* Billings, but there is a most striking similarity in the cranidium and pygidium of the two forms, and the description of the thoracic segments of *M. salteri* corresponds to that of the thoracic segments of *Corynexochus.* Both have a " broad, deep groove extending outwards to the tips, which are bent down." The lower limestones of Point Levis are formed of limestone boulders in a limestone matrix, and *Salterella pulchella* Billings, a Lower Cambrian species from l'Anse au Loup, has been found there.[2] This fact prepares us to expect other Lower Cambrian fossils in some of the boulders, as is the case at Bic, Trois Pistoles, and other localities along the south shore of the St. Lawrence River.

Formation and locality.—Lower Cambrian: (41k) 80 feet (21 m.) above base of limestone series, or zone 2; Point Amour, east side of Forteau Bay, and (41 i and 41m) the surface of *Olenellus* layer; top of hill back of Mrs. Flinn's house, Forteau, Forteau Bay, north shore Straits of Belle Isle, Labrador; (2 o) limestone boulders in conglomerate, on shore at east entrance to harbor at Bic; also (2r) in a cut on

[1] Canadian Nat. and Geol., Vol. 8, 1863, p. 210, text fig.

[2] Bull. U. S. Geol. Survey, No. 30, 1886, p. 144, pl. 13, figs. 3, 3*a*.

the Intercolonial Railway, 2 miles (3.2 km.) west of Bic Railway station, both in Rimouski County, Quebec, all in Canada.

Subfamily DOLICHOMETOPINÆ

Genus BATHYURISCUS Meek

Bathyuriscus MEEK, 1873, Sixth Ann. Rept. U. S. Geol. Surv., Terr., p. 484. (Suggests name for species *haydeni* if the latter belongs to a new genus.)

Bathyuriscus WALCOTT, 1866, Bull. U. S. Geol. Surv., No. 30, p. 215. (Describes and discusses genus with illustration of new species, *B. howelli*.)

Bathyuriscus MATTHEW, 1897, Trans. Royal Soc. Canada, 2d ser., Vol 3, Sec. 4, p. 195. (Considers *Bathyuriscus* a subgenus of *Dolichometopus* Angelin.)

Bathyuriscus MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 63. (Suggests that *Bathyuriscus* may have been derived from *Anomocare*.)

Bathyuriscus LORENZ, 1906, Zeits. deuts. geol. Gesells., Vol. 58, pp. 74, 75. (Decides that *Bathyuriscus* is a subgenus of *Dolichometopus*.)

Bornemannia WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, pp. 213, 214. (Name given in lists of fossils from 1*c* and 3 of geologic section.)

Bathyuriscus GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 287. (Brief description of genus and illustration of *B. productus, B. howelli,* and *B. rotundatus*.)

Since the publication of my note on *Bathyuriscus* in 1886[1] considerable additional material has been found that adds to our knowledge of the genus and the species grouped under it.

Description.—General form elongate oval. Axial and pleural lobes strongly defined. Cephalon transversely semi-circular with genal angles extended backward in spines of medium length. Marginal border narrow in front, widening towards the genal angles where it merges into the genal spines; posterior margin and occipital ring usually defined by a well-marked furrow. The facial sutures cut the anterior margin a short distance each side of the line of the greatest expansion of the glabella and curve obliquely inward to the anterior base of the eye lobes; encircling the latter, they continue obliquely outward and cut the posterior margin a short distance inside the base of the genal spine. Glabella elongate, usually expanded towards the broadly rounded front and narrowing slightly midway; marked by three or four pairs of short lateral furrows, the posterior two pairs of which are extended obliquely inward and backward, and the anterior more or less obliquely forward. Occipital segment well-defined and in some species rising at the center to form a base for

[1] Bull. U. S. Geol. Survey, No. 30, pp. 215-216.

a small, sharp spine that extends obliquely upward and backward. Fixed cheeks moderately convex, with strong postero-lateral limbs, narrow central section, and small antero-lateral limbs; a well-defined palpebral ridge curves around the eye and extends obliquely forward across the cheek to the dorsal furrow beside the glabella; palpebral lobes narrow and varying in length from one-fourth to more than one-half the length of the cephalon. Free cheeks of medium width and terminating posteriorly in a sharp genal spine; visual surface of eye narrow and elongate.

Thorax with 8 to 9 segments. (The genotype has nine.) Each segment has a node or spine on the median axis and a very distinct, rather broad pleural furrow that extends nearly to the outer termination of the segment. In the type species, *B. haydeni* (pl. 46, fig. 2), a narrow, elongate triangular ridge extends from the axis out into the pleural furrow; this character is strongest in *B. ornatus* (pl. 46, fig. 4), and traces of it are found in all the species now referred to the genus. The pleural lobes of the segments curve slightly backward and terminate in a short falcate point.

Pygidium semicircular in outline. Median axis nearly as long as the pygidium, convex and marked by several transverse furrows that outline transverse segments; both furrows and segments extend across the pleural lobe to a narrow border.

Hypostoma of *B. howelli*, rounded subtriangular in outline; central portion oval, convex and separated posteriorly by a shallow curved furrow, from a low transverse tubercle; a narrow margin merges into rather large posterior wings that form the anterior section of the hypostoma.

Surface with many very fine, irregular, inosculating ridges that give it a roughened appearance, and when slightly weathered it looks as though there were fine shallow pits thickly scattered over the surface.

Dimensions.—The largest specimen of the dorsal shield of the type species *B. haydeni*, has a length of 21 mm.; *B. rotundatus* reaches 52 mm., while *B. ornatus* is 21 mm., and *B. anax* 37 mm. in length. Separated cranidia and pygidia of *B. anax* indicate that the entire dorsal shield sometimes was 90 mm. or more in length. *B.* (*Poliella*) *primus*, the oldest known species, has a length of 30 mm., and fragments indicate individuals that were 46 mm. long. The largest entire dorsal shield of *B. atossa* has a length of 41 mm., but fragments and pygidia indicate that the species sometimes attained a length of 50 mm. or more.

Genotype.—*Bathyuriscus haydeni* Meek.

Stratigraphic range.—As far as known, *Bathyuriscus* and its subgenus *Poliella* are found in the upper portion of the Lower Cambrian as *B.* (*Poliella*) *primus*, which is abundant in the siliceous strata occurring in the upper part of the Mount Whyte formation, and *B. batis*, which is associated with *Mesonacis gilberti* in southwestern Nevada, *B. belus* and *B. belesis* from Montana and doubtfully of Lower Cambrian age. The greatest development of the genus is in the Middle Cambrian formations: *Bathyuriscus* (*Poliella*) *probus* in the Marjum formation of Utah; *B. haydeni* and *B.* (*Poliella*) *powersi* occur in the Gallatin limestone; *B. howelli*, in the Chisholm shale; *B. adæus*, *B.* (*Poliella*) *occidentalis*, *B. ornatus*, and *B. rotundatus*, *Ogygopsis* shale of Stephen formation; *B.* (*Poliella*) *sylla*, Chetang formation; *B. anax*, *B.* (*Poliella*) *anteros*, *B. atossa*, *B. ? bithus*, and *B.* (*Poliella*) *caranus*, Spence shale horizon at base of the Ute formation; *B. bantius*, sandstone of Rome formation; *B.* (*Poliella*) *balus*, shales of the York formation, and *Bathyuriscus* sp., Conasauga formation.

Geographic distribution.—Nevada, *B. howelli* and *B. batis*. Northern Utah, *B. anax* and *B. bithus*. Southern Idaho, *B.* (*Poliella*) *anteros*, *B. atossa*, *B. belesis*, and *B. belus*. Montana, *B. haydeni* and *B.* (*Poliella*) *powersi*. Eastern British Columbia at Mount Stephen, *B. adæus*, *B. rotundatus*, *B. ornatus*, *B.* (*Poliella*) *occidentalis*, and *B.* (*Poliella*) *primus*. The last species also occurs near Lake Louise in western Alberta. In the Robson Peak section, British Columbia, *Bathyuriscus* (*Poliella*) *sylla*. Eastern Tennessee, *B. bantius*. Central Pennsylvania, *B.* (*Poliella*) *balus*. The genus appears to be represented in Asia by *B. stoliczkai*, which is found in Kashmir, northern India.

Observations.—I have heretofore included *Ogygia producta* Hall and Whitfield under *Bathyuriscus*, but with present information it is necessary to refer that species and several others to the genus *Dolichometopus*, as they differ materially from the typical forms of *Bathyuriscus*. My impression of the latter genus was so influenced in 1886 by the study of fragments of (*Ogygia*) *Bathyuriscus producta* Hall and Whitfield that I concluded that that species was a typical form of *Bathyuriscus* and when I found a species not generically related to *producta* I listed it as a new genus and species.[1]

Another confusing form was the species now known as *Bathyuriscus* (*Poliella*) *occidentalis* (Matthew) (pl. 46, fig. 3). Matthew's

[1] *Bornemannia prima*: Smithsonian Misc. Coll., Vol. 53, 1908, pp. 213, 214.

illustration was diagrammatic and did not suggest the closely allied form now described as *B.* (*Poliella*) *primus* (pl. 46, fig. 6), which occurs 2,150 feet lower in the Mt. Stephen section.

The Lower Cambrian species *Bathyuriscus* (*Poliella*) *primus* has a small compact pygidium similar in relative size to that of *B.* (*Poliella*) *powersi*, which is associated with the type species, *B. haydeni*, which has a large pygidium.

Comparison of Bathyuriscus with Other Genera.

Zacanthoides.[1]—The type species of *Bathyuriscus, B. haydeni*, has a very distinctive cranidium characterized by (1) a narrow, convex glabella that expands in front of the anterior pair of lateral furrows; (2) a pair of posterior, oblique lateral furrows that are united by a transverse furrow, and (3) three pairs of short lateral furrows, the anterior two of which extend obliquely forward. This combination of characters is almost identical with that of the glabella of *Zacanthoides spinosus* Walcott.[2] The cranidium of *B. haydeni* has also a long palpebral lobe, narrow fixed cheek, short frontal limb much like those of *Z. spinosus*, and the occipital spines on the thoracic segments are of the same type in the two forms, but the pygidia of the two genera are unlike and very distinctive.

Corynexochus.—It may be compared with the Lower and Middle Cambrian genus *Corynexochus*,[3] from which it differs in the form of its glabella, pleural furrows of thoracic segments, and pygidium.

Vanuxemella.[4]—It differs from *Vanuxemella* in the same way as from *Corynexochus*, and *Vanuxemella* has but five thoracic segments.

Dolichometopus.[5]—It differs from this genus in having distinct glabellar furrows, more numerous thoracic segments, and in the presence of distinct furrows on the pleural lobes of the pygidium. The two genera, however, closely approach each other in such species as *Dolichometopus ? bessus* (pl. 51, figs. 3, 3*a*-*b*) and *Bathyuriscus bantius* (pl. 49, figs. 2, 2*a*-*c*).

Genesis.—*Bathyuriscus* appears to have been derived from a Lower Cambrian ancestor that also gave rise to the allied genera *Dolichometopus, Corynexochus* and its subgenus *Bonnia.*

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[1] American Jour. Sci., Vol. 36, 1888, p. 165. Smithsonian Misc. Coll., Vol. 53, 1908, p. 26.

[2] Canadian Alpine Jour., Vol. 1, No. 2, 1908, pl. 4, fig. 1.

[3] Pal. Scandinavica, Angelin, 1854, p. 59, pl. 33, fig. 9.

[4] Smithsonian Misc. Coll., 1916, Vol. 64, No. 3, p. 220.

[5] Pal. Scandinavica, Angelin, 1854, p. 72.

Species of Bathyuriscus.—The species now referred to *Bathyuriscus* are:

Bathyuriscus adæus Walcott (pl. 47, fig. 3), Middle Cambrian.
Bathyuriscus anax Walcott (pl. 48, fig. 1), Middle Cambrian.
Bathyuriscus atossa Walcott (pl. 48, fig. 2), Middle Cambrian.
Bathyuriscus bantius Walcott (pl. 49, fig. 2), Middle Cambrian.
Bathyuriscus batis Walcott (pl. 48, fig. 4), Lower Cambrian.
Bathyuriscus belesis Walcott (pl. 50, fig. 1), Lower ? Cambrian.
Bathyuriscus belus Walcott (pl. 50, fig. 2), Lower ? Cambrian.
Bathyuriscus ? bithus Walcott (pl. 47, fig. 4), Middle Cambrian.
Bathyuriscus haydeni (Meek) (pl. 46, fig. 2), Middle Cambrian.
Bathyuriscus howelli Walcott (pl. 47, fig. 1), Middle Cambrian.
Bathyuriscus manchuriensis Walcott (pl. 49, fig. 4), Middle Cambrian.
Bathyuriscus ornatus Walcott (pl. 46, fig. 4), Middle Cambrian.
Bathyuriscus rotundatus (Rominger) (pl. 47, fig. 2), Middle Cambrian.
Bathyuriscus stoliczkai Reed, Middle ? Cambrian.
Bathyuriscus sp. undt. (1) (pl. 49, fig. 3), Middle Cambrian.
Bathyuriscus ? sp. undt. (2) (pl. 65, fig. 5), Middle Cambrian.
Bathyuriscus (*Poliella*) *anteros* Walcott (pl. 46, fig. 5), Middle Cambrian.
Bathyuriscus (*Poliella*) *balus* Walcott (pl. 49, fig. 1), Middle Cambrian.
Bathyuriscus (*Poliella*) *caranus* Walcott (pl. 46, fig. 8), Middle Cambrian.
Bathyuriscus (*Poliella*) *occidentalis* (Matthew) (pl. 46, fig. 3), Middle Cambrian.
Bathyuriscus (*Poliella*) *powersi* Walcott (pl. 46, fig. 1), Middle Cambrian.
Bathyuriscus (*Poliella*) *primus* Walcott (pl. 46, fig. 6), Lower Cambrian.
Bathyuriscus (*Poliella*) *probus* Walcott (pl. 65, fig. 2), Middle Cambrian.
Bathyuriscus (*Poliella*) *sylla* Walcott (pl. 48, fig. 3), Middle Cambrian.
Bathyuriscus (*Poliella*) sp. undt. (1) (pl. 46, fig. 7), Lower Cambrian.

Generic reference of species heretofore placed under Bathyuriscus and now referred to other genera is as follows:

Bathyuriscus asiaticus Lorenz = *Dolichometopus.*
Bathyuriscus (*Kootenia*) *dawsoni* Walcott = *Kootenia.*
Bathyuriscus productus (Hall and Whitfield) = *Dolichometopus.*
Bathyuriscus pupa Matthew = *Bathyuriscus occidentalis* Matthew.
Bathyuriscus senectus Matthew (1897) = *Corynexochus.*
Bathyuriscus sp. undt. (from China) Walcott = *Dolichometopus.*
Bathyuriscus sp. undt. Walcott (1899) = *Anomocare ?*

BATHYURISCUS ADÆUS, new species

Plate 47, figs. 3, *3a-c*

This species is closely related to *Bathyuriscus rotundatus.* It differs: (a) in having a broader space between the front of the glabella and the anterior edge of the cranidium; (b) in having the outer angle of the thoracic pleura (genal angle) less rounded and the triangular tubercle at the inner end of the pleural furrow somewhat

stronger; (c) in having one or two more rings on the median lobe of the pygidium, and in having the first segment of the pygidium extended as a short spine beyond the border.

There are nine thoracic segments and six segments in the axis of the pygidium that continue across the pleural lobes to the margin.

The largest specimen of the dorsal shield in the collection has a length of 40 mm.

Formation and locality.—Middle Cambrian: (58j) Stephen formation; about 1,900 feet (579 m.) above the Lower Cambrian and 3,100 feet (945 m.) below the Upper Cambrian, near the base of the limestone forming 2 of the Stephen formation, on the east side of Mount Stephen about 3,000 feet (914 m.) above the Canadian Pacific Railway track (north of the tunnel), 3 miles (4.8 km.) east of Field; and (61j) yellow-weathering band of calcareo-argillaceous shale; west slope of Mount Field, near Burgess Pass ridge, about 3,000 feet above Field, on Canadian Pacific Railway, British Columbia, Canada.

BATHYURISCUS ANAX, new species

Plate 48, figs. 1, 1*a-d*

Bathyuriscus productus (Hall and Whitfield) WALCOTT (In part), 1886, Bull. 30, U. S. Geol. Surv., pl. 30, figs. 1, 1*a*, 1*b*, 1*g*, 1*h*. (The specimens illustrated by the above figures are all from Big Cottonwood Canyon, Wasatch Mountains, and are now considered as belonging to the species *B. anax*.)

This fine species is readily separated from the species now referred to as *Dolichometopus productus* by the form of its glabella and the character of its pygidium. It also has one more thoracic segment. It differs from *B. atossa* in having one less thoracic segment (8), a longer palpebral lobe and broader axial lobe on thorax and pygidium; *B. atossa* also has an occipital spine that has not yet been seen on *B. anax*. It is closely related to *B. rotundatus* except that it has one less thoracic segment and longer palpebral lobes.

The specimens from Big Cottonwood Canyon (30a) show only the cranidium and pygidium, but these appear to be identical with similar parts from further north in the Wasatch Range (55e), and they are not identical with *Dolichometopus productus*, with which I placed them in 1886.

The largest entire dorsal shield has a length of 40 mm., and the outer surface is slightly roughened by shallow pits.

Formation and locality.—Middle Cambrian: (55e) Spence shale horizon of the Ute formation; about 100 feet (30.5 m.) above the Brigham quartzite, at the mouth of the first small canyon south of

Wasatch Canyon, east of Lakeview Ranch, Boxelder County; and (30a) shale on north side of Big Cottonwood Canyon, 1 mile (1.6 km.) below Argenta, in the Wasatch Mountains southeast of Salt Lake City, Salt Lake County, both in Utah.

BATHYURISCUS ATOSSA, new species

Plate 48, figs. 2, *2a-b*

In size and general characters this species at once suggests *B. anax* (pl. 48, fig. 1) and *B. rotundatus* (pl. 47, fig. *2a*). The three species also occur at about the same horizon in the Middle Cambrian section. *Bathyuriscus atossa* differs from *B. anax* in having one more thoracic segment (9), a shorter palpebral lobe and relatively narrower axial lobe both in thorax and pygidium.

From *B. rotundatus* it differs in having a relatively narrower median axis in thorax and pygidium, and the axial lobe is shorter in the pygidium. The tubercle at the inner end of the pleural furrow is also stronger than in the other species mentioned. I identified this species with *B. rotundatus* in my field notes, but a closer comparison seems to indicate that although closely allied they differ in detail sufficiently to distinguish them as distinct species.

Formation and locality.—Middle Cambrian: (55c) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

BATHYURISCUS BANTIUS, new species

Plate 49, figs. 2, *2a-c*

This species is represented by only the cranidia and associated pygidia as casts in a shaly sandstone of the Rome formation. The cranidia vary in outline, especially in the glabella, owing mainly to distortion caused by compression and some lateral motion in the sandy matrix. The one illustrated (fig. 2) has a length of 9 mm. and it appears to have nearly its original form and convexity. The glabella is marked by the usual oblique posterior pair of furrows and three shorter pairs, the anterior of which slope a little forward from the dorsal furrow, beside the glabella. The eye lobes are much like those of *B. haydeni.* The associated pygidia have from 6 to 7

rings in the axial lobe that are well defined by narrow furrows on the pleural lobes. Surface unknown.

There appears to be a gradation in size among the cranidia from 9 mm. up to 24 mm. in length, and the associated pygidia from 3 mm. to 23 mm. in length.

It is possible that a second species is represented in the larger specimens, but with the material now in hand this is too uncertain to base a species on.

No traces of the test or outer surface have been found.

At locality 9a this species is associated with:

Lingulella desiderata (Walcott)
Lingulella similis (Walcott)
Ptychoparia sp. undt.

At locality 11 it is associated with:

Lingulella ino (Walcott)
Lingulella tarpa (Walcott)

And at locality 14a with:

Micromitra alabamaensis (Walcott)
Obolus willisi (Walcott)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella similis (Walcott)
Wimanella saffordi (Walcott)
Ptychoparia sp. undt.

Formation and locality.—Middle Cambrian: Rome formation: (9) Shaly sandstone on southeastern slope of ridge 1 mile (1.6 km.) north of the northwest corner of Harlan Knob, about 4 miles (6.4 km.) northeast of Rogersville; and (9a) on the south shore of the Holston River at Melinda Ferry, 5 miles (8 km.) southwest of Rogersville, both in Hawkins County; (11) sandstones and shales of the Rome formation, about 1 mile (1.6 km.) east of Post Oak Springs, Roane County; (11b) in ridge, at Woods Creek Gap, 6 miles (9.6 km.) northeast of Knoxville; also (12b) southeast end of McAnnallys Ridge, 12 miles (19.3 km.) northeast of Knoxville; and (14a) along First Gap Creek, 4 miles (6.4 km.) north-northeast of Knoxville, all three in Knox County, and all in Tennessee.

BATHYURISCUS BATIS, new species

Plate 48, figs. 4, 4*a*

This fine species has 8 thoracic segments, a strong glabella, and a large pygidium. It occurs in a hard siliceous rock in which the

specimens are compressed and slightly distorted. No traces of the test or outer surface have been seen.

The glabella is not well preserved in any of the seven specimens before me. One of them is similar in outline to the glabella of *Protypus hitchcocki* (Whitfield),[1] but that species is quite unlike *B. batis* in other characters. One glabella suggests *Dorypyge* and three the glabella of *B. primus*.

The pygidium with its 5 or 6 anchylosed segments is not unlike that of *B. haydeni* and *B. atossa*.

The largest dorsal shield has a length of 38 mm.

The only associated species is *Mesonacis gilberti* (Meek) Walcott.

Formation and locality.—Lower Cambrian: (59p) Millers Mountain, 10 miles (16 km.) north of Columbus and west of Belleville, Esmeralda County, Nevada.

BATHYURISCUS BELESIS, new species

Plate 50, figs. 1, 1*a*-*i*

The form from locality 4v I referred to "*Bathyuriscus productus*"[2] in my field notes, but comparison shows that it varies in having the anterior half of the glabella more expanded and stronger indications of glabellar furrows. The pleural lobes of the thoracic segments are also terminated in a more abrupt point than those of *D. productus*. The adult pygidium is sometimes similar to that of *D. productus* (pl. 53, fig. 4*a*), but a pygidium 2 mm. in length has the anchylosed pleural segments as clearly defined as in the type specimens of *B. haydeni*, while the larger pygidia have more or less traces of grooves or ridges on the pleural lobes. The pleural ridges on a small pygidium 2 mm. in length are more rounded and the furrows narrower than in adult pygidia or in the pygidia of *B. belus* (pl. 50, figs. 2, 2*a*-*c*) or *B. anax* (pl. 48, figs. 1, 1*a*-*d*).

The cranidium of *B. belesis*, while similar in form to that of *B. belus*, differs in its shorter, more anterior palpebral lobe and larger postero-lateral limb and the absence of well-defined glabellar furrows.

Exterior surface unknown. The largest cranidium in the collection has a length of 23 mm. and the largest pygidium 18 mm.

[1] Bull. American Mus. Nat. Hist., Vol. 1, 1884, p. 148, pl. 14, fig. 13.

[2] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, Walcott, Cambrian sections of the Cordilleran area, pp. 202-203.

The fauna associated with this species at the type locality (4v) as far as identified includes:

Micromitra (*Iphidella*) *pannula* (White)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Acrothele colleni Walcott
Acrothele panderi Walcott
Wimanella simplex Walcott
Ptychoparia sp.
Olenopsis americanus Walcott
Vanuxemella contracta Walcott

A single pygidium from locality 4q appears to be identical with the pygidia of this species. It is associated with:

Micromitra (*Iphidella*) *nyssa* Walcott
Micromitra (*Iphidella*) *pannula* (White)
Wimanella simplex Walcott
Acrothele colleni Walcott
Ptychoparia 3 spp.
Zacanthoides

Formation and locality.—Lower ? Cambrian: (4v) About 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, in a shale which corresponds in stratigraphic position to shale No. 6 of the Dearborn River section,[1] Gordon Creek, 6 miles from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

Also doubtfully from (locality 4q) about 315 feet (96 m.) above the unconformable base of the Cambrian and 190 feet (57.9 m.) above the top of the quartzitic sandstones in a shale which corresponds in position to the upper part of shale No. 6 of the Dearborn River section,[1] on the ridge between Gordon and Youngs Creeks, about halfway between Gordon Mountain and Cardinal Peak, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

BATHYURISCUS BELUS, new species

Plate 50, figs. 2, *2a-d*

This species attains a larger size than either *B. anax* or *B. atossa,* and differs from them in minor details of the cranidium and pygidium. There is a faint trace of pleural furrows on the lateral lobes of the pygidium, whereas in *B. anax* and *B. atossa* they are strongly defined. The variations from *B. belesis* are mentioned under that species.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, Walcott, Cambrian sections of the Cordilleran area, p. 202.

The largest cranidium has a length of 19 mm. and the largest pygidium has a length of 22 mm. and a width of 37 mm.

There are six cranidia and six pygidia in the collection at locality 4w that were associated in the same thin layer of sandstone. The associated fossils are *Wimanella simplex, Ptychoparia* sp. undt., and *Zacanthoides* sp. undt. As the two latter do not have a pygidium of the *Bathyuriscus* type, I think we are fairly safe in tentatively considering the pygidia as belonging with the cranidia referred to *Bathyuriscus.*

An associated hypostoma of the *Bathyuriscus* form has the surface of its central portion marked by fine, sharp, irregularly concentric ridges. None of the cranidia or pygidia appear to have the outer surface of the test. They occur as casts in a very fine, chocolate-colored, arenaceous shale.

Formation and locality.—Lower ? Cambrian: (4w) About 315 feet (96 m.) above the unconformable base of the Cambrian and 190 feet (57.9 m.) above the top of the quartzitic sandstones in a shale which corresponds in position to shale No. 6 of the Dearborn River section,[1] on Youngs Creek, about 5 miles (8 km.) from its junction with Danaher Creek; and (8j) about 575 feet (175.3 m.) above the unconformable base of the Cambrian in a shale which corresponds in position to shale No. 4 of the Dearborn River section,[1] on the ridge between Gordon and Youngs Creeks, about halfway between Gordon Mountain and Cardinal Peak; both in Ovando quadrangle (U. S. G. S.), Powell County, Montana.

BATHYURISCUS ? BITHUS, new species

Plate 47, figs. 4, 4*a*

This species is based on two pygidia that indicate a form larger than any known species of *Bathyuriscus,* in this respect approaching *Dolichometopus tontoensis* (pl. 51, figs. 1, 1*f,* 1*g*). The axial lobe has six indicated segments and a terminal section, the segments extending obliquely backward on the pleural lobes and nearly across the broad, flattened margin.

Surface slightly roughened by fine, irregular, inosculating ridges that on the border are subparallel to the outer margin.

The larger pygidium has a portion of a thoracic segment attached to it. It has a length of 33 mm. The smaller pygidium is 20 mm. in length.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, Walcott, Cambrian sections of the Cordilleran area, p. 202.

These pygidia are placed in *Bathyuriscus* rather than *Dolichometopus* on account of the distinctness of the segments on the pleural lobes.

Formation and locality.—Middle Cambrian: Spence shale member of the Ute formation: (55c) about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

Also, Spence shale horizon of the Ute formation: (55e) about 100 feet (30.5 m.) above the Brigham quartzite, at the mouth of the first small canyon south of Wasatch Canyon, east of Lakeview Ranch, Boxelder County, Utah.

BATHYURISCUS HAYDENI (Meek)

Plate 46, figs. 2, *2a-b*

Bathyurus ? haydeni MEEK, 1873, Sixth Ann. Rept., U. S. Geol. Surv. Terr., p. 482. (Detailed description of species and comparison with species of several genera.)

Description.—General form elliptical to elongate oval; moderately convex, with pleural lobes slightly flattened. Cephalon probably semicircular with genal angles extended backward in short spines as in closely allied species. Glabella narrow, convex, and expanding in advance of the palpebral lobes to the broadly rounded front; occipital furrow strong, arching slightly forward from the sides towards the center; occipital ring strong, convex, and rising towards the center as though it may have had a node or short spine near its posterior margin; the posterior pair of glabellar furrows are quite strong; they commence about opposite the center of the palpebral lobe and extend obliquely backward and inward to a shallow connecting transverse furrow which delimits a transverse posterior lobe about as wide as the occipital ring; the next succeeding anterior pair of furrows are short and inclined a little backward, while the third pair extended directly inward as slight, short indentations, and the fourth very short and distinct pair are directed slightly forward.

Fixed cheeks narrow, with strong elongate palpebral lobes which extend across them anteriorly as a narrow ridge to the dorsal furrow, the lobe on each side being separated by a narrow furrow; the eye lobe appears to have been about one-fifth the length of the head; anteriorly the fixed cheek merges into a narrow area and posteriorly

into an elongate postero-lateral limb that is furrowed by a well-defined groove that delimits a rim that is very narrow near the axial lobe and broader towards the facial suture. Free cheeks unknown.

"Thorax consisting of 9 segments; axial lobe very narrow, or only about two-thirds as wide as the lateral lobes, tapering gradually backward, and moderately convex; lateral lobes flattened, and lower than the axial; pleuræ broadly and deeply furrowed, and having their free ends apparently falcate.

"Pygidium intermediate between semicircular and semielliptical, its length being about two-thirds its breadth, while its posterior margin is rounded in outline, and its anterior nearly straight across; mesial lobe as narrow, proportionally, as that of the thorax, convex, tapering very gradually backward, and nearly reaching the posterior border, showing five or six well-defined segments, with space enough for one or two more behind those; lateral lobes flat, with five or six broadly furrowed segments that extend to, but not upon, a very narrow, slightly thickened and flattened, smooth margin." [1]

To the above may now be added: A node or short spine occurs at the center of each segment of the convex axial lobe of the thorax and pygidium. There is an oval swelling on each side of the axial segments of the thorax close to the longitudinal dorsal furrow and a triangular node-like swelling in the pleural furrow of each segment with the narrow base of the triangle abutting against the dorsal furrow. This peculiar form of swelling is best seen in *B. ornatus* (pl. 46, figs. 4, 4*a*). The terminal section of the pygidium is continued down as a low ridge to the slightly incurved posterior margin.

Surface smooth or finely roughened by very minute irregular ridges or granules.

Dimensions.—The largest entire specimen has a length of 30 mm. Associated pygidia indicate a length of 40 mm. for some specimens.

Observations.—The material illustrating *B. haydeni* is not as good as for some other species, but it is sufficient to show the principal characters and that its pygidium is unlike that of any other species referred to the genus.

Formation and locality.—Middle Cambrian: (302) Gallatin limestone; east of West Gallatin River, above Gallatin, Gallatin County, Montana.

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[1] Quoted from Meek's description, p. 483.

BATHYURISCUS HOWELLI Walcott

Plate 47, figs. 1, 1*a-b*

Bathyuriscus howelli WALCOTT, 1886, Bull. U. S. Geol. Surv., No. 30, p. 216, pl. 30, figs. 2, 2*a*. (Describes and illustrates species.)

Bathyuriscus howelli WALCOTT, 1888, American Jour. Sci., 3d ser., Vol. 36, p. 165. (Considers *Embolimus* [=*Bathyuriscus*] *rotundatus* Rominger [1887] identical with this species.)

Not *Bathyuriscus howelli* MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 50. (Describes the young of *Embolimus* [=*Bathyuriscus*] *rotundatus* Rominger, following Walcott in identification of the latter species as *B. howelli.*)

Bathyuriscus howelli TOLL, 1899, Mem. l'Acad. Imp. Sci. St. Petersburg, 8th ser., Vol. 8, No. 10, p. 30, pl. 2, fig. 11. (Identifies a pygidium from the Cambrian of Siberia as *B. howelli,* and illustrates same.)

Not *Bathyuriscus howelli* WOODWARD, 1902, Geol. Mag., Dec. 4, Vol. 9, p. 532, text fig. 2. (Discusses species when studying specimens of *Embolimus* [=*Bathyuriscus*] *rotundata* Rominger and illustrates by a diagrammatic figure of the latter species.)

Bathyuriscus howelli PACK, 1906, Jour. Geol., Vol. 14, p. 296, pl. 2, figs. 2, 2*a*. (Comments on species and illustrates a cranidium and pygidium.)

Not *Bathyuriscus howelli* WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 198. (Named as occurring in Spence Shale. The species is now referred to *Bathyuriscus rotundatus* (Rominger).)

Bathyuriscus howelli GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 287, fig. 1592. (Brief description and reproduces Walcott's figure of 1886.)

This is a rather rare form in the collections I have seen from the vicinity of Pioche. It occurs in a compact argillaceous shale with a group of species characteristic of the Middle Cambrian fauna. Very little has been added to our knowledge of the species since its first description in 1886. Pack (1906) illustrates a glabella that has a fourth pair of small, short, anterior furrows that with the third pair extend slightly forward from the dorsal furrow.

In 1881 [1] when reviewing Dr. Rominger's paper on "Primordial Fossils from Mt. Stephen" [2] and some collections from Mt. Stephen I identified *Embolimus* [= *Bathyuriscus*] *rotundatus* Rominger as identical with *B. howelli.* Two errors were made in this paper: I mistook the crushed-down, postero-lateral limb of the cranidium of *B. howelli* for a thoracic segment, thus giving the latter species nine thoracic segments instead of eight, and owing to rather unfavorable specimens of *B. rotundatus* I did not note other differences which

[1] American Jour. Sci., 3d ser., Vol. 36, 1888, p. 165.

[2] Proc. Acad. Nat. Sci., Philadelphia, 1887, pp. 12-19, pl. 1.

with fine specimens for comparison I find to exist. The differences between the two species consist principally in the greater expansion of the frontal portion of the glabella of *B. howelli*. It also has more elongate palpebral lobes, narrower postero-lateral limbs of the cranidium, one less thoracic segment and a shorter median lobe and a broader border on the pygidium. These differences are shown by the illustrations of the two species on plate 47, figures 1 and 2.

The elongate triangular tubercle at the inner end of the thoracic pleural furrows is small in *B. howelli* as compared with *B. ornatus* (pl. 46, fig. 4), but it is about as strong as in *B. haydeni* (pl. 46, fig. 2) and *B.* (*Poliella*) *powersi* (pl. 46, fig. 1).

Formation and locality.—Middle Cambrian: (31) Chisholm shale; Chisholm mine, southwest slope of Ely Mountains, 3 miles (4.8 km.) northwest of Pioche, Lincoln County, Nevada.

Mr. F. J. Pack records this species from several mine dumps that cut into the Chisholm shale about 2 miles west of Pioche.[1]

BATHYURISCUS MANCHURIENSIS Walcott

Plate 49, figs. 4, 4*a-c*

Bathyuriscus manchuriensis WALCOTT, 1911, Smithsonian Misc. Coll., Vol. 57, No. 4, pp. 97-99, pl. 16, fig. 4. (Described and discussed as a new species essentially as below.)

Bathyuriscus manchuriensis WALCOTT, 1913, Research in China, Vol. 3, p. 219, pl. 23, figs. 2, 2*a-f*. (Describes and illustrates species.)

This species is founded on numerous specimens of the cranidium, free cheeks, thoracic segments, and pygidium that are compressed in a fine argillaceous shale. Unfortunately, there are no entire specimens of the dorsal shield.

As restored by combining the free cheeks and cranidium, the cephalon is semicircular in outline and moderately convex. It is bordered by a narrow, slightly rounded margin that is separated by a sharply defined, narrow furrow from the glabella and the slope of the free cheeks. The posterior border is very narrow, elevated, and separated from the fixed cheek by strongly defined furrow; the palpebral lobes are narrow and a little less than one-fourth the length of the cephalon. Genal angles extended into short, sharp, backward-curving spines. The cranidium is broad at the base, narrowing toward the front; the antero-lateral limbs are very small and disappear where the palpebral lobe touches the dorsal furrow; the

[1] Jour. Geol., Vol. 14, 1906, p. 297.

postero-lateral limbs and narrow fixed cheeks merge into each other so as to form transversely subtriangular areas, with the narrow palpebral lobes on their front outer margins.

Glabella large, subquadrangular in outline, and separated from the fixed cheeks by clearly defined dorsal furrows; its sides are nearly parallel or slightly diverging; front broadly rounded, almost transverse; surface marked by five pairs of furrows, the posterior of which extends obliquely across the posterior portion nearly to the center and separates a small triangular lobe on each side; the next two anterior pairs of furrows are short and extend inward at right angles to the side of the glabella; the anterior pair is nearly opposite the front end of the palpebral lobe; the anterior furrows are short and extend obliquely inward subparallel to the front margin of the glabella. Occipital ring narrow at the sides, widening toward the center, where it is marked by a small, sharp node a little back of the transverse center. Free cheeks large and surmounted on the inner side by a narrow eye-lobe. The facial sutures cut the posterior margin a little within the genal angle and extend obliquely inward and slightly forward to the base of the eye-lobes; curving over and around the eye-lobes, they extend forward and downward, cutting the front margin on a line with the posterior base of the eye-lobe. Number of thoracic segments unknown. Single specimens of the segments show that the axial lobe was nearly as wide as the pleural lobes, that it was moderately convex, and that a small node occurs at the center of each segment near the posterior margin; also that on the outer side of each segment a rounded transverse node is outlined from the main body of the segment by a slightly oblique transverse furrow; pleural lobes nearly flat out to the geniculation, where they curve gently downward; each pleura has a furrow that is broad at its inner end next to the axial lobe and gradually narrows to the geniculation, where it terminates within the somewhat broadly rounded, outer extremity; in well-preserved specimens a rounded ridge starts near the inner end of the pleural furrow and extends outward one-fourth of the length of the furrow.

The associated pygidia are semicircular, with the anterior margin almost transverse in the compressed specimens. The axial lobe is large and quite distinctly marked; it is divided by three transverse furrows into three rings and a terminal section that ends posteriorly just within the outer border; a small node occurs near the posterior margin at the center of each ring; five anchylosed segments are

outlined on the pleural lobes by furrows that progressively curve more and more backward from the first to the posterior one, which adjoins the terminal segment; the furrows all terminate within the narrow, slightly flattened border.

The casts of the outer surface indicate that it was smooth or minutely granulose.

This species appears to be quite distinct from any that has been described. The quadrangular glabella with nearly parallel sides distinguishes it from *Bathyuriscus howelli* Walcott.

Formation and locality.—Middle Cambrian: (35 o, 36g, 36h) Fuchóu series, shales about 130 feet (40 m.) above the white quartzite; collected near a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria, China.[1]

Collected by J. P. Iddings and Li San.

BATHYURISCUS ORNATUS Walcott

Plate 46, figs. 4, *4a-b*

Bathyuriscus ornatus Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, p. 39, pl. 1, figs. 1-3. (Describes and illustrates species.)

Bathyuriscus ornatus Walcott, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 3, fig. 3. (Republishes fig. 1 of previous paper.)

This form was described in detail in 1908. It is so strongly marked by the triangular tubercle in the thoracic pleural furrow and by the absence of genal spines that there is little chance of its being mistaken for any other known species of the genus.

Formation and locality.—Middle Cambrian: (14s) About 2,300 feet (701 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian, in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.

BATHYURISCUS ROTUNDATUS (Rominger)

Plate 47, figs. 2, *2a-b*

Embolimus rotundata Rominger, 1887, Proc. Acad. Nat. Sci. Phil., p. 16, pl. 1, figs. 4, 5. (Describes and illustrates species.)

Bathyuriscus howelli Walcott, 1888, American Jour. Sci., 3d ser., Vol. 36, p. 165. (Considers *Embolimus rotundatus* Rominger as identical with *Bathyuriscus howelli*.)

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[1] For general section giving stratigraphic relations, see Blackwelder, Research in China, Vol. 1, Pt. 1, 1907, p. 92.

Bathyuriscus howelli MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 50. (Follows Walcott in identifying specimens of *Embolimus* [=*Bathyuriscus*] *rotundatus* Rominger as *Bathyuriscus howelli* and describes specimens of the young of the species.)

Bathyuriscus howelli WOODWARD, 1902, Geol. Mag., Dec. 4, Vol. 9, p. 532, text fig. 2. (Follows Matthew when studying specimens of *Embolimus* [=*Bathyuriscus*] *rotundatus* Rominger.)

Bathyuriscus rotundatus WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 41. (Mentions species in comparisons with *Bathyuriscus ornatus.*)

Bathyuriscus rotundatus WALCOTT, 1908, Idem, p. 198. (Lists species as *Bathyuriscus howelli* as occurring in Spence Shale.)

Bathyuriscus rotundatus WALCOTT, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 4, fig. 2. (Illustrates species by figure which is reproduced as fig. 2, pl. 47 of this paper.)

Bathyuriscus rotundatus GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 288, fig. 1593. (Brief description and reproduction of Walcott's figure of 1908.)

As mentioned under *Bathyuriscus howelli,* I identified this species by error with *B. howelli.* It differs from the latter in having a less expanded glabella, less elongate palpebral lobes, broader postero-lateral limbs on the cranidium; one more thoracic segment (nine) and a longer median lobe and narrower margin on the pygidium. The differences are shown by figures 1 and *2a,* plate 47.

A single pygidium was found in a thin-bedded limestone (locality 57j) just beneath the *Ogygopsis* shale on Mount Stephen that is closely related to the pygidium of this species.

Formation and locality.—Middle Cambrian: Stephen formation; (14s) about 2,300 feet (701 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian, in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen; (57j) about 2,000 feet (609.6 m.) above the Lower Cambrian in the limestone forming 2 of the Stephen formation, just east of the "fossil bed" on the northwest slope of Mount Stephen; and (35k) Burgess shale member of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, all three above Field on the Canadian Pacific Railway, British Columbia, Canada.

BATHYURISCUS STOLICZKAI Reed

Bathyuriscus ? stoliczkai REED, 1910, Mem. Geol. Surv., India, ser. 15, Vol. 7, Mem. No. 1, Cambrian Fossils of Spiti, p. 37, pl. 5, figs. 5-8. (Species described and figured.)

Mr. F. R. C. Reed has given a very detailed description of this species, and the illustrations are excellent. He very kindly sent me

the specimens for examination two years ago, and from notes made before returning them I find that I considered the species to belong to the genus *Bathyuriscus*. Mr. Reed thought that there were 12 or 13 thoracic segments. I could not make out more than eleven, and the casts of the type specimens now before me do not appear to have more than eleven. The back of the occipital segments shows in the specimen from which his figure 7 is taken, and the last segment referred to the thorax in his figure 8 seems to belong to the pygidium.

The form of the cranidium, thoracic segments, and pygidium relate this species most nearly to *B. rotundatus* (pl. 47, fig. 2).

Formation and locality.—Middle Cambrian: Valley of the Parahio, Spiti, Kashmir, India.

BATHYURISCUS, species undetermined (1)

Plate 49, figs. 3, 3*a*

A species of *Bathyuriscus* not unlike *B. atossa* (pl. 48, fig. 2) occurs in the Conasauga shales of Alabama. A distorted cranidium, a free cheek, six thoracic segments and a fairly good pygidium occur on fragments of the shale, but as they are not united and there is only one specimen of each part, I do not think it worth while to base a species on them. The pygidium has a length of 10 mm. with an axial lobe 8 mm. in length; the latter has four well-defined rings that are extended across the pleural lobes as flattened bands separated by narrow furrows; there is also a trace of a shallow pleural furrow.

Formation and locality.—Middle Cambrian: (16e) Conasauga formation; cut on East and West Railway, 1 mile (1.6 km.) southwest of Piedmont, Calhoun County, Alabama.

BATHYURISCUS ? species undetermined (2)

Plate 65, fig. 5

A large species, related to *Bathyuriscus adæus* (pl. 47, figs. 3, 3*a*) by the form of the pygidium, has a single pair of sharp spines projecting from the antero-lateral angles; it has eight rings and a terminal section in the axial lobe; the anchylosed segments are shown on the pleural lobes as seven or eight shallow furrows separated by narrow ridges; a narrow strong border merges into the border spines which extend obliquely backward.

Formation and locality.—Middle Cambrian: (11p) Marjum formation; limestone of 1*e* of section, about 2,000 feet (609.6 m.) above the Lower Cambrian and 1,010 feet (307 m.) below the Upper Cam-

brian, in the long cliff about 2.5 miles (4 km.) east-southeast of Marjum Pass, House Range, Millard County, Utah.

POLIELLA, new subgenus

The species *B.* (*Poliella*) *powersi, B.* (*Poliella*) *anteros, B.* (*Poliella*) *occidentalis, B.* (*Poliella*) *primus, B.* (*Poliella*) *caranus, B.* (*Poliella*) *sylla, B.* (*Poliella*) *balus,* and *B.* (*Poliella*) *probus* all suggest by their small and different pygidia a subgeneric distinction from the typical species of *Bathyuriscus, B. haydeni,* and for them I propose the subgenus *Poliella.*

The range in the number of thoracic segments is from 7 (*B.* (*Poliella*) *caranus* (pl. 46, fig. 8)) to 11 (*B.* (*Poliella*) *powersi* (pl. 46, fig. 1)). *Bathyuriscus* (*Poliella*) *powersi,* of the Middle Cambrian, with its 11 segments and small pygidium, is a primitive form of *Poliella,* while *B.* (*Poliella*) *primus,* of the Lower Cambrian, has a more highly developed *Dolichometopus*-like cephalon, eight thoracic segments, and a very well developed though small pygidium.

Genotype.—*Bathyuriscus* (*Poliella*) *anteros* Walcott.

Observations.—Most of the species of *Poliella* are small. Of the two larger species, *B.* (*Poliella*) *primus* has a length of 27 mm., and *B.* (*Poliella*) *balus* about 30 mm.

The stratigraphic range and geographic distribution are given under the genus *Bathyuriscus* (p. 330).

BATHYURISCUS (POLIELLA) ANTEROS, new species

Plate 46, fig. 5

This neat species has a relatively large cephalon, nine thoracic segments and a small pygidium. Of the eight entire dorsal shields found the largest has a length of 18 mm. It is similar in general character to *B.* (*Poliella*) *occidentalis* (pl. 46, fig. 3), but differs in having a larger palpebral lobe and a smaller pygidium in proportion to the thorax. How much this may be owing to the imperfection of the specimen of *B.* (*Poliella*) *occidentalis,* it is difficult to determine. The latter occurs in a hard, very fine-grained arenaceous shale, and *B.* (*Poliella*) *anteros* in a moderately compact argillaceous shale in which the specimens retain much of their original convexity.

Bathyuriscus (*Poliella*) *anteros* differs from *B. haydeni* in many details of the cranidium, thorax, and especially the pygidium. A comparison with *B.* (*Poliella*) *primus* will be found under that species.

Formation and locality.—Middle Cambrian: (**55c**) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

BATHYURISCUS (POLIELLA) BALUS, new species

Plate 49, figs. 1, 1*a*-*g*

This is one of the species occurring in an argillaceous shale that has been compressed and distorted more or less by the movement in the sediment. Fortunately its remains are abundant and afford data from which a very fair conception of the species may be obtained.

Bathyuriscus (*Poliella*) *balus* has the elongate eye lobe and small pygidium characteristic of *B.* (*Poliella*) *powersi* (pl. 46, fig. 1) and *B.* (*Poliella*) *primus* (pl. 46, figs. 6, 6*a*-*b*). Specimens occur with nine and others with 10 thoracic segments. The sharp spines on the occipital ring of the cranidium and the median lobe of all of the thoracic segments are similar to those of *B.* (*Poliella*) *powersi*. Surface not preserved.

The larger specimens range from 25 to 30 mm. in length.

This species is associated with:

Lingulella sp. undt. (**48d**)
Acrothele yorkensis Walcott (**48d**)
Acrotreta (**48d**)
Cystid plates (**48**)
Agnostus (**48, 48d**)
Ptychoparia (**48**)

Formation and locality.—Middle ? Cambrian: York ? formation; (**48**) cellar diggings, corner of Penn and North Streets; and (**48d**) argillaceous shales in railroad cut alongside of Gas House, both in City of York, York County, Pennsylvania.

BATHYURISCUS (POLIELLA) CARANUS, new species

Plate 46, fig. 8

This fine little species, 10 mm. in length, is represented in the collections by one specimen of the dorsal shield exclusive of the free cheeks. It has seven thoracic segments, the pleural furrows of which are broad near the axial lobe and narrowing gradually toward the abrupt outer termination of the segment. Surface slightly roughened by very fine, irregular inosculating edges.

This small species is somewhat similar to *B.* (*Poliella*) *anteros* (pl. 46, fig. 5); it differs in having seven instead of nine thoracic segments, more abrupt terminations of the thoracic segments, a proportionally larger glabella and broader pygidium.

Formation and locality.—Middle Cambrian: (55c) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

BATHYURISCUS (POLIELLA) OCCIDENTALIS (Matthew)

Plate 46, fig. 3

Dolichometopus occidentalis Matthew, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, No. 2, p. 49, pl. 2, fig. 2. (Describes species and illustrates with a somewhat diagrammatic figure.)

Bathyuriscus pupa Matthew, 1899, Idem, p. 51, pl. 2, fig. 5. (This appears to be a laterally compressed specimen of *B. occidentalis.*)

Bathyuriscus occidentalis Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, p. 41. (Places species in genus *Bathyuriscus.*)

Bathyuriscus occidentalis Walcott, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 3, fig. 2. (Illustrates type specimen.)

This small and rare species has a relatively broader glabella, nine thoracic segments, and a short pygidium with one or two rings in its axial lobe; the triangular swelling in the pleural furrow next to the dorsal furrow is scarcely visible. Only one specimen, and that a matrix, has been found and identified. This has a length of 12.5 mm.

For comparison with *B.* (*Poliella*) *anteros* (pl. 46, fig. 5), see description of the latter (p. 349).

Formation and locality.—Middle Cambrian: (14s) Stephen formation; *Ogygopsis* shale, northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railroad, British Columbia, Canada.

BATHYURISCUS (POLIELLA) POWERSI, new species

Plate 46, fig. 1

This very clearly defined species is similar to *B. haydeni* in cranidium and thorax, except that it has 11 thoracic segments and a more expanded frontal lobe to the glabella. Its greatest variation is in the pygidium, which has but three rings and a terminal section in its axial lobe and corresponding smaller pleural lobes and a rather strong border. The base of a small spine is preserved at the center of the

median lobe of each thoracic segment and apparently on the occipital ring of the cranidium. The differences between it and other species are clearly shown by the illustrations.

The only known dorsal shield preserving cranidium, thorax, and pygidium has a length of 21 mm. The surface is similar to that of *B. haydeni*. The type specimen was collected by Mr. Sydney Powers of a Harvard University geological party, and is now in the Museum of Comparative Zoölogy.

Formation and locality.—Middle Cambrian: Gallatin limestone; Pole Creek, a branch of Cherry Creek, Gallatin County, Montana.

BATHYURISCUS (POLIELLA) PRIMUS (Walcott)

Plate 46, figs. 6, 6*a-d*

Bornemannia prima Walcott, 1908, Canadian Alpine Jour., Vol. 1, No. 2, p. 241. (Listed.)

Bornemannia prima Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, pp. 213, 214. (Lists species in geological section under new generic name *Bornemannia*. This was prior to the present study of the genus *Bathyuriscus*.)

The description of *B. haydeni* applies to this species fairly well until the pygidium is considered. The pygidium of *B. haydeni* (pl. 46, figs. 2, 2*b*) is much larger in proportion to the thorax and cephalon and it also varies in outline, number of segments, length of axial lobe, and width of pleural lobes. The short, relatively small pygidium of B. (*Poliella*) *primus* is similar to that of *B.* (*Poliella*) *anteros* (pl. 46, fig. 5) and *B.* (*Poliella*) *occidentalis* (pl. 46, fig. 3).

Three specimens referred to *B.* (*Poliella*) *primus* have nine segments (fig. 6*b*) and six have eight thoracic segments each.

The occipital segment rises and extends slightly backward at the center, where the base of a small spine is shown on several specimens. A similar spine also occurs at the center of the axial lobe of each thoracic segment.

There is considerable variation in the depth and size of the postero-lateral limb of the cranidium in associated specimens and from more or less widely separated localities. The two extremes of this character are shown in figures 6, 6*a* and 6*b*, the postero-lateral limb of the latter being much deeper and larger, which is the case in the greater number of specimens.

The largest dorsal shield in the collection has a length of 27 mm.

Bathyuriscus (*Poliella*) *primus* is the oldest known species of the subgenus. It occurs at several horizons of the Mount Whyte forma-

tion[1] in the Mount Stephen section. Its horizon is indicated by its being stratigraphically beneath both *Olenellus canadensis* and *Mesonacis gilberti* and *Corynexochus* (*Bonnia*) *fieldensis,* all of which are characteristic of the upper portion of the Lower Cambrian fauna.

At locality 35m *B.* (*Poliella*) *primus* is associated with *Agraulos statór* Walcott.

At locality 35e with:

Micromitra (*Paterina*) *wapta* Walcott
Obolus parvus Walcott
Acrothele colleni Walcott
Hyolithes billingsi Walcott
Olenopsis agnesensis Walcott
Ptychoparia sp.
Albertella sp.

At locality 57r with:

Micromitra (*Paterina*) *labradorica* var.
Micromitra (*Iphidella*) *pannula* (White)
Acrotreta sagittalis taconica (Walcott)
Ptychoparia 3 spp.

At locality 57e with:

Acrothele colleni Walcott
Acrotreta sagittalis taconica (Walcott)
Scenella varians Walcott
Stenotheca elongata Walcott
Albertella sp.
Olenellus canadensis Walcott

At locality 57t with:

Hyolithes billingsi Walcott
Scenella varians Walcott
Ptychoparia, 2 spp.
Olenopsis agnesensis Walcott

At locality 58s with:

Micromitra (*Paterina*) *labradorica* var.
Micromitra (*Iphidella*) *pannula* (White)
Acrotreta sagittalis taconica (Walcott)
Ptychoparia 3 spp.

Formation and locality.—Lower Cambrian: Mount Whyte formation: (35e) Dark-gray, siliceous shale of the Lakes Louise and Agnes Cambrian section: amphitheatre between Popes Peak and Mount Whyte, south of Lake Agnes, south of Laggan, on the Canadian

[1] Canadian Alpine Journal, Vol. 1, No. 2, (Sept.) 1908, pp. 240-242.

Pacific Railway; (35m) *Albertella* zone; 3 miles (4.8 km.) southwest of the head of Lake Louise, on east slope of Mount Whyte; (58d) Castle Mountain section, and (58t) shale, both just below the big cliff on the east shoulder of Castle Mountain, north of Canadian Pacific Railway, all in Alberta, Canada.

Localities 58k, 57e, 57r, 57t, and 58s are also Mount Whyte formation, slightly different horizons; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

BATHYURISCUS (POLIELLA) PROBUS, new species

Plate 65, figs. 2, *2a*

This species is represented by several cranidia and associated pygidia. The cranidium is much like that of *B. haydeni* and *B.* (*Poliella*) *powersi* (see pl. 46, figs. 1, 2). The associated pygidia differ very materially from both species. The short axial lobe, almost concave margin, and elongate outline suggest reference to *Coosia* rather than to *Bathyuriscus.* It is quite probable that the discovery of an entire dorsal shield would result in referring *B.* (*Poliella*) *probus* to a new genus or subgenus.

Formation and locality.—Middle Cambrian: (11 o) Limestone of Marjum formation about 2,750 feet (838.2 m.) above the Lower Cambrian and 300 feet (92 m.) below the Upper Cambrian,[1] at the base of the limestone forming 1*a* of the Marjum formation; about 4 miles (6.4 km.) southeast of Antelope Springs in the spur at the junction of the Deseret and Swasey Spring roads, House Range, Millard County, Utah.

BATHYURISCUS (POLIELLA) SYLLA, new species

Plate 48, figs. 3, *3a-f*

This species belongs to that section of the genus *Bathyuriscus* represented by *B.* (*Poliella*) *anteros* (pl. 46, fig. 5). It has the expanded frontal portion of the glabella, falcate termination of the thoracic segments, and relatively small pygidium as compared with that of *B. haydeni* (pl. 46, figs. 2, *2b*). One specimen preserves the pygidium and four thoracic segments, but none shows the entire thorax. The glabella has four pair of furrows; the two anterior are

[1] This distance is given as 1,650 feet (502.9 m.) [Monogr. 51, U. S. Geol. Surv., 1912, p. 179], but since that reference was published the Weeks formation has been referred to the Upper Cambrian [Smithsonian Misc. Coll., Vol. 64, 1916, p. 161], which removes 1,390 feet of strata from the Middle Cambrian to the Upper Cambrian in the House Range section.

faint and short and extend obliquely forward, and an occipital spine is indicated by the rising of the center of the occipital ring with a broken spot at the highest point.

The expansion of the glabella is much like that of *B. howelli* (pl. 47, fig. 1).

Formation and locality.—Middle Cambrian: (61 o) Chetang formation; gray, shaly limestone in massive beds; on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

BATHYURISCUS (POLIELLA), species undetermined (1)

Plate 46, fig. 7

This species is represented by two relatively large pygidia that have the general outline of the pygidium of *B.* (*Poliella*) *primus* (pl. 46, figs. 6, 6*a*). The anterior ring of the axial lobe is clearly outlined and carries a median spine with a large base; the second and third rings do not carry a spine; the axial rings extend obliquely across the pleural lobes, but they are not marked by pleural furrows. Surface of test not preserved.

Formation and locality.—Lower Cambrian: (35e) Mount Whyte formation; dark-gray, siliceous shale of the Lakes Louise and Agnes Cambrian section; amphitheatre between Popes Peak and Mount Whyte, south of Lake Agnes, south of Laggan, on the Canadian Pacific Railway, in western Alberta, Canada.

Genus DOLICHOMETOPUS Angelin

Dolichometopus ANGELIN, 1852, Pal. Scandinavica, Pt. 1, Crustacea formationis transitionis, Lipsiæ, p. 72. (Genus named and described under family Corynexochidæ.)

Dolichometopus ANGELIN, 1854, Idem. (Reprint of the preceding.)

Not *Dolichometopus ?* BILLINGS, 1865, Pal. Foss., Vol. 1, pp. 268-269, 352. (Refers three Canadian species to the genus, none of which belong to it.)

Dolichometopus ANGELIN, 1878, Pal. Scandinavica, 3d ed., Holmiæ, p. 72. (Reprint of description of 1852 and 1854.)

Not *Dolichometopus* WOODWARD, 1884, Geol. Mag., new ser., Dec. 3, Vol. 1, p. 343. (Quotes Angelin's description and adds further details. Species described now referred to *Redlichia* Cossmann.)

Dolichometopus ZITTEL, 1885, Handbuch d. Pal., Vol. 2, Munich, p. 599. (Brief description of genus.)

Dolichometopus MILLER, 1889, North American Geol. and Pal., p. 545. (Repeats description, and adds etymology of name as from Gr. *dolichos,* long, and *metope,* panel or space between two hollows. Doubts its being an American genus.)

Dolichometopus KOKEN, 1896, Die Leitfossilien, Leipzig, p. 15. (Briefly described under family Paradoxididæ.)

Dolichometopus FRECH, 1897, Leth. geog., Pt. 1, Leth. Pal., Vol. 2, p. 65. (Relates the genus *Niobe* to *Dolichometopus,* and identifies the latter with *Bathyuriscus* Walcott.)

Dolichometopus MATTHEW, 1897, Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, p. 184. (Discusses the genus and illustrates Angelin's type.)

Dolichometopus MATTHEW, 1897, Idem, p. 195. (Suggests that Billings's *Bathyuriscus,* extended by Walcott, is a subgenus of *Dolichometopus.*)

Amphoton LORENZ, 1906, Zeits. deuts. geol. Gesells., Vol. 58, Pt. 2, p. 75. (Described as a new genus.)

Dolichometopus LORENZ, 1906, Idem, p. 74, text figure. (Compares *Dolichometopus* and *Bathyuriscus.*)

Dolichometopus WALCOTT, 1913, Research in China, Vol. 3, Carnegie Inst. of Washington, Pub. No. 54, p. 215. (Briefly discusses genus and refers Lorenz's *Amphoton* to *Dolichometopus.*)

General form elongate oval, distinctly trilobed and rather convex. Cephalon semicircular with postero-lateral angles prolonged in sharp spines; cranidium large, with strong fixed cheeks, long postero-lateral limbs and inconspicuous antero-lateral limbs; glabella more or less broadened anteriorly and slightly contracted midway; very faint traces of three pairs of short glabellar furrows are to be seen on cast of the interior of the test of specimens of the type species[1] and more definite furrows on *D. productus*; frontal limb narrow, slightly rounded or flattened and with a furrow of varying size and depth between it and the glabella; occipital ring broad and defined from the glabella by a shallow, gently concave furrow; none of the species appear to have an occipital spine although it might be expected on *D. tontoensis;* palpebral lobes elongate and varying in the various species from one-fifth (*D. tontoensis*) to three-fifths of the length of the cranidium (*D. productus*); free cheeks of medium size and terminating in a strong spine at the genal angle. The facial sutures cut the posterior border of the cephalon at about the genal angles and then extend inward and forward to the base of the narrow eye lobes near which they curve; in front of the eyes the sutures extend forward with a gentle outward and then inward curve so as to cut the front margin on a line with the sides of the front portion of the glabella.

Thorax with seven segments; axial lobe strong and marked by a short median spine or tubercle on each segment, *D. tontoensis,* or apparently smooth, *D. productus*; pleural lobes with each segment

[1] Specimens of the cranidium of *D. suecicus* from the Andrarum limestone at Andrarum are now in the collection of the United States National Museum (C. D. W.).

having a distinct furrow crossing from the inner anterior side to the posterior outer side; the anterior outer half of each segment has a sloping faceted surface and the segments terminate in a more or less sharp falcate end.

Pygidium large with the anterior margin arched slightly forward; axial lobe convex with from five to seven transverse segments and a terminal section; pleural lobes with a broad margin and more or less faintly marked by shallow, narrow furrows that serve to indicate the outward extension of the anchylosed segments of the axial lobe.

Surface of the type species and of all species as far as known punctate (except possibly *D. acadicus* Matthew) and also marked by very fine irregular raised lines.

Dimensions.—Fragments of *D. suecicus* indicate that the entire dorsal shield was about 65 mm. in length in some specimens. Examples of *D. tontoensis* in the collection are 95 mm. in length.

Genotype.—Dolichometopus suecicus Angelin.

Stratigraphic range.—As far as known *Dolichometopus* is confined to Middle Cambrian formations.

Geographic distribution.—The genotype *D. suecicus* comes from Andrarum, Sweden. *Dolichometopus acadicus* Matthew, a somewhat closely related species to *D. suecicus,* is found in the province of New Brunswick, Canada. *Dolichometopus productus* ranged on both the Atlantic and Pacific sides of the North American Continent. It has its representative in northern Georgia and eastern Tennessee; northern Arizona and northern Utah. *Dolichometopus tontoensis* is found in the Grand Canyon of the Colorado in northern Arizona. *Dolichometopus bion* in southern Idaho; *D. baton* and *D. ? bessus* in central Montana, and *D. boccar* along the Rocky Mountain Continental Divide on the line of the Canadian Pacific and Grand Trunk railroads. In Eastern China the genus is abundantly represented by *D. (?) alceste, D. (?) deois, D. (?) derceto,* and *D. (?) dirce.*

Observations.—The species referred to *Dolichometopus* and *Bathyuriscus* in this paper have long been confused by me and by others. Now I think we may define *Dolichometopus* as characterized by seven thoracic segments, a glabella almost free from lateral furrows, and a pygidium only faintly marked on its axis by transverse furrows that are extended onto the pleural lobes only as a trace, if at all. The genus *Bathyuriscus* (restricted) has from eight to nine thoracic segments, a more expanded glabella marked by distinct lateral furrows, and a pygidium with distinct axial rings and anchylosed segments on the pleural lobes.

Dr. Fritz Frech[1] says of *Dolichometopus* and allied genera: "*Niobe* is directly connected with *Dolichometopus* (*Dol. suecicus* Ang., Tril., Taf. 37, fig. 9), as Brögger already conjectured. *Dolichometopus* is identical with *Bathyuriscus* Walcott. The American recognized species with complete specimens accord with Asaphidæ in respect to the size of the pygidium, the course of the facial sutures, and the number of rings (8). Also *Symphysurus* is to be traced down from *Dolichometopus*."

On text plate B, facing p. 39, he places *Ogygopsis klotzi* (Rominger) and *Bathyuriscus occidentalis* Matthew in the genus *Dolichometopus,* although he leaves Matthew's *Bathyuriscus pupa* (a probable synonym of *Bathyuriscus occidentalis*) under the genus *Bathyuriscus.*

Dr. Th. Lorenz[2] concludes that *Bathyuriscus* is a subgenus of *Dolichometopus.* He says: "The genus *Bathyuriscus* is without doubt closely related to the Swedish genus *Dolichometopus* Angelin. The difference consists in that *Bathyuriscus* has a stronger relief, deeper glabellar furrows, and on the back part of the fixed cheeks a ridge, which is produced by the posterior course of the facial suture. *Dolichometopus* has a perfectly flat, furrowless glabella; furthermore the facial suture extends from the posterior eye angles quite direct to the posterior border without cutting out a narrow ridge as in *Bathyuriscus.* There is also a difference between the two genera in the position of the eye curves. The cause of this is that in *Dolichometopus* the posterior eye angles are situated farther from the glabella. Despite all this the form relationship of the two genera is very close, so that I hold *Bathyuriscus* as a subgenus of *Dolichometopus,* as Matthew did. Equal rank for the two genera, as Frech has done in his Lethæa, I cannot commend. It is further worthy of note that the related genus *Dolichometopus* is a guide fossil [Leitfossil] for the uppermost Middle Cambrian in Sweden."

He then compares *D. acadicus* Matthew and his own *Bathyuriscus asiaticus* Lorenz and says: "Herein the generic distinction between *Dolichometopus* and *Bathyuriscus* finds expression. They agree in the two semicircular eye lobes, the erect position of the eyes, the club-shaped glabella flattened towards the front and the flat occipital furrow. The shell structure in both is of the finest granulation. Nevertheless identification of *Dolichometopus acadicus* Matthew and *Bathyuriscus asiaticus* is not therefore permissible."[3]

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[1] Leth. geog., Pt. 1, Leth. Pal., Vol. 2, 1897, p. 65.

[2] Zeitschrift der deutschen geologischen Gesellschaft, Vol. 58, Pt. 2, 1906, p. 74.

[3] Idem, p. 75.

Asiatic species.—The eastern Asiatic species of the genus all differ from the Swedish and American species in their associated pygidia. The latter have fewer segments in the axial lobe and more distinct prolongation of the axial segments on the pleural lobes. The pygidia are more like those of the species of *Bathyuriscus* with small pygidium such as *B.* (*Poliella*) *powersi* (pl. 46, fig. 1) and *B.* (*Poliella*) *primus* (pl. 46, fig. 6). If we had entire specimens of the dorsal shield of *D.* (*?*) *deois* and other Asiatic species, so that there could be no doubt that the associated pygidia belong with the cranidia, I should not hesitate to make a new subgenus of *Dolichometopus* to include them. *Dolichometopus* (*?*) *deois* (pl. 54, figs. 1, 1*a-h*) is the most abundant of the Chinese species in the form of dismembered parts of the dorsal shield, and it is found in both shale and limestone.

There also appears to be a subgenus of *Dolichometopus* indicated by *D. ? bessus* (pl. 51, fig. 3). It is characterized by a smaller pygidium very much as in the group of species of the subgenus *Poliella* (p. 349) which are those species of *Bathyuriscus* characterized by a small pygidium. Further collecting and study may result in separating *D. ? bessus* and several of the species illustrated on plate 54 as subgeneric species of *Dolichometopus*.

Species of Dolichometopus.—The species now referred to *Dolichometopus* are:

Dolichometopus acadicus Matthew (pl. 53, fig. 1), Middle Cambrian.
Dolichometopus (*?*) *alceste* Walcott (pl. 54, fig. 3), Middle Cambrian.
Dolichometopus baton Walcott (pl. 51, fig. 2), Middle Cambrian.
Dolichometopus ? bessus Walcott (pl. 51, fig. 3), Middle Cambrian.
Dolichometopus bion Walcott (pl. 52, fig. 2), Middle Cambrian.
Dolichometopus boccar Walcott (pl. 52, fig. 1), Middle Cambrian.
Dolichometopus (*?*) *deois* Walcott (pl. 54, fig. 1), Middle Cambrian.
Dolichometopus (*?*) *derceto* Walcott (pl. 54, fig. 4), Middle Cambrian.
Dolichometopus (*?*) *dirce* Walcott (pl. 54, fig. 5), Middle Cambrian.
Dolichometopus ? expansus (Walcott) (pl. 53, fig. 5), Middle Cambrian.
Dolichometopus productus (Hall and Whitfield) (pl. 53, fig. 2), Middle Cambrian.
Dolichometopus suecicus Angelin (pl. 50, figs. 3, 4), Middle Cambrian.
Dolichometopus tontoensis Walcott (pl. 51, fig. 1), Middle Cambrian.

Generic reference of species heretofore placed under Dolichometopus and now referred as follows:

Dolichometopus (*?*) *convexus* Billings = *Bolbocephalus* Whitfield ?
Dolichometopus (*?*) *gibberulus* Billings = *Platycolpus* Raymond ?
Dolichometopus hyrie Walcott = *Anomocare.*
Dolichometopus occidentalis Matthew = *Bathyuriscus.*
Dolichometopus (*?*) *rarus* Billings = *Bolbocephalus* Whitfield ?
Dolichometopus tatei Woodward = *Redlichia* Cossmann.

DOLICHOMETOPUS ACADICUS Matthew

Plate 53, figs. 1, 1*a-c*

Dolichometopus acadicus MATTHEW, 1897, Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, p. 185, pl. 3, figs. 6*a-d*. (Described and figured as a new species.)

Dolichometopus acadicus Matthew, LORENZ, 1906, Zeits. deuts. geol. Gesells., Vol. 58, Pt. 2, p. 75. (Compares *D. acadicus* with his *Bathyuriscus asiaticus*.)

Original description.—" Body covered with a very smooth test.

" Head-shield margined all round and having an intramarginal furrow. Eyes large, furnished with a semicircular orbital lobe. The facial suture curves backward and downward behind the eyes, and has a direct extension forward before the eyes. Glabella distinctly outlined, bent downward in front, subclavate, without furrows, rather squarish in front, extending to the anterior marginal fold, about twice as long as the width at the base. Occipital ring lenticular in outline, divided from the glabella by a shallow furrow. Fixed cheeks narrow, width about half of that of the glabella at the base. Posterior angles of the middle piece produced backward and bent downward. The eye lobes are as long as the width of the glabella in front. . . . .

" A pygidium, which also occurs with the above heads and cheeks, is not unlike that of an *Anomocare,* but differs in having a blunter and stouter rachis than is usual with pygidia of this genus; we regard it as probably the pygidium of the *Dolichometopus*. It has a rather narrow prominent rachis, having four faintly marked rings, besides the more distinct half-ring in front; the side lobes have three faintly marked ribs, besides that at the front margin; the lateral margins are flattened and without a fold.

Sculpture.—" This consists of a minute granulation, made visible only with a lens.

Size.—" Length of the head-shield, 11 mm.; width of the middle piece of the head, 10 mm. Length of the movable cheek, 10 mm.; width, 5 mm. Length of pygidium, 6 mm.; width, 10 mm. . . . .

" This species differs from the Swedish form (*Dolichometopus suecicus*) by Angelin,[1] in having a more direct suture before and behind the eye, and a longer eye lobe. It differs from the same species as figured by Brögger[2] in the course of the dorsal suture, and in the less numerous joints in the rachis of the pygidium."

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[1] Pal. Scand., pl. 37, figs. 9, 9*b-c*.

[2] Om Paradox. skifrene v. Krekling, Nyt Mag. for Naturvidensk., 1879, pl. 3, figs. 12, 12*a*.

On account of not being able at present to obtain the type specimens of this species, the original figures of Matthew are reproduced on plate 53, figures 1, 1*a-c*.

Formation and locality.—Middle Cambrian: Hastings Cove, about 0.75 mile (1.2 km.) from Torryburn Station on the Intercolonial Railroad, New Brunswick, Canada. Collection of Dr. George F. Matthew.

DOLICHOMETOPUS (?) ALCESTE Walcott

Plate 54, figs. 3, 3*a-b*

Dolichometopus alceste WALCOTT, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 94. (Species described as below.)

Dolichometopus alceste WALCOTT, 1913, Research in China, Vol. 3, p. 215, pl. 22, figs. 3, 3*a-b*. (Described and illustrated.)

This species occurs at the same locality as *D.* (?) *deois,* but not in the same bed of limestone. It differs from *D.* (?) *deois* in having a much more convex glabella with nearly parallel sides. Glabella marked by a posterior pair of furrows, extending inward and backward so as nearly to cut off a small, subtriangular lobe at the base of the glabella; also three pairs of short, faintly impressed furrows that extend in at right angles to the side of the glabella; occipital furrow and ring unknown; dorsal furrow shallow but well defined.

Fixed cheeks very narrow; they slope down into the strong furrow just within the narrow palpebral lobe and anteriorly slope down to the frontal limb; the rim of the palpebral lobe crosses the narrow fixed cheek, forming a very short palpebral ridge; frontal limb short, nearly flat.

The exterior surface, under a strong lens, shows a few fine, scattered punctules. The inner surface of the frontal limb, where exposed by a breaking away of a portion of the shell, is strongly punctate.

The only specimen of the glabella of this species has a length of 12 mm., with a width at the palpebral ridges of 8 mm.; the frontal limb has a length of 1.5 mm.

Formation and locality.—Middle Cambrian: (C4) In limestone nodules at the base of the lower shale member of the Kiu-lung group,[1] 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shantung, China.

[1] Blackwelder, Research in China, Pub. No. 54, Carnegie Institution of Washington, Vol. 1, Pt. 1, 1907, Chap. 2, Stratigraphy of Shan-tung, pp. 37 and 40 (second list of fossils), and fig. 10 (bed 4), p. 38.

DOLICHOMETOPUS BATON, new species

Plate 51, figs. 2, *2a-b*

This species is preserved in a fine, dark argillaceous shale. The largest dorsal shield has a length of nearly 60 mm. As far as can be determined, the surface of the test was finely punctate. Seven thoracic segments of the usual form except that the extremities narrow more rapidly to a sharp, slightly backward curving point.

Dolichometopus baton differs from *D. suecicus, D. productus, D. boccar* and *D. bion* by its smaller palpebral lobe and termination of the pleural lobes of the thoracic segments. From *D. ? bessus* is differs in position and relative size of palpebral lobes and more transverse pygidium. The thoracic segments are quite similar in both species.

Formation and locality.—Middle Cambrian: (3j) Wolsey ? shale; above the quartzitic sandstones in a shale corresponding in position to the upper part of shale No. 6 of the Dearborn River section,[1] about 6 miles (9.6 km.) west-northwest of Scapegoat Mountain on the Continental Divide between Bar Creek and the headwaters of the south fork of the North Fork of Sun River, Coopers Lake quadrangle (U. S. G. S.), Powell County, Montana.

DOLICHOMETOPUS ? BESSUS, new species

Plate 51, figs. 3, *3a-c*

Fragments of this species contained in a fine, buff-colored, argillaceous shale indicate that the dorsal shield attained a length of 30 mm. A smaller entire specimen has a length of 22 mm. The outer surface of the test appears to have been punctate and the seven thoracic segments terminate in sharp, gently curved points very similar to those of *D. baton* (pl. 51, fig. 2).

Dolichometopus ? bessus differs from its most nearly related species, *D. baton*, by its smaller palpebral lobe and its more elongate pygidium which is also more abruptly curved backward at the anterolateral margin.

This species has many of the characters of *Bathyuriscus bantius* (pl. 49, figs. 2, *2a*), and brings the genera *Dolichometopus* and *Bathyuriscus* very close to each other.

Formation and locality.—Middle Cambrian: (62i) Wolsey shale interbedded in upper part of Flathead sandstone, Sixteen Mile Can-

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[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, Walcott, Cambrian sections of the Cordilleran area, p. 202.

yon, 0.25 mile (0.4 km.) below Sixteen Post Office, Meagher County, Montana.

DOLICHOMETOPUS BION, new species

Plate 52, figs. 2, *2a-c*

Bathyuriscus productus (Hall and Whitfield) WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 198. (Named in list of fossils found in 1 of Spence shale.)

This is one of the largest species of the genus. It differs from *D. productus* (pl. 53, figs. 2, *2a-d,* 3, 3*a,* 4, 4*a*) in position of the palpebral lobes and more expanded glabella. The associated pygidium has a shorter axial lobe and broader border. Outer surface of test in cast nearly smooth.

Only one cranidium has been found. This has a length of 16 mm. The largest associated pygidium has a length of 32 mm. The outlines of the pygidium vary owing to impression and distortion in the argillaceous shale.

Formation and locality.—Middle Cambrian: (55c) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

DOLICHOMETOPUS BOCCAR, new species

Plate 52, figs. 1, *1a-f*

This interesting species at once suggests *D. productus* (pl. 53, figs. 2, *2a-d,* 3, 3*a,* 4, 4*a*). It differs in the more posterior position of the palpebral lobes in relation to the length of the glabella. Compare figures 3*a* and 4*a,* plate 53, with figures 1 and 1*c,* plate 52. The pygidia of the two species are very much alike.

The stratigraphic horizon of the specimen of *D. productus* from Mount Stephen, British Columbia, is in the lower portion of the *Ogygopsis* shale [1] and that of *D. boccar* about 200 feet below in limestones of *2d* in the Mount Bosworth section.[2]

A species apparently identical with this was found in a loose block of limestone on the southwest side of Moose Pass at the head of Moose River in which the glabella and palpebral lobes have about the same form, also the pygidium.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 210.

[2] Idem, p. 211.

The largest dorsal shield has a length of 50 mm. A large cranidium indicates that some entire specimens were at least 70 mm. in length.

The outer surface of the test is preserved on only one specimen of the cranidium. This shows exceedingly fine, irregular, waving, sharp elevated lines. This outer surface usually adheres to the matrix, the inner layer of the test appearing smooth or punctate according to the condition of preservation.

Specimens of a cranidium and pygidium occur in Middle Cambrian limestone in northern Utah that resemble those parts in *Dolichometopus boccar* except that the axis of the pygidium is proportionally shorter. This form was identified as *Bathyuriscus=Dolichometopus productus* (Hall and Whitfield),[1] but with our present information the identification is not considered good. The best specimens of *D.* cf. *boccar* are from locality (55p) Middle Cambrian: Langston formation; massive-bedded, bluish-gray limestone 44 feet; 400 feet (120 m.) above the Lower Cambrian Brigham formation; about 7 miles (14.4 km.) above the mouth of Blacksmith Fork Canyon and 10 miles (16.1 km.) east of Hyrum, Cache County, Utah. Fragments of a similar form occur in the same section in the Langston formation about 50 feet higher in 1*a* of the section. These were originally identified as *Bathyuriscus=Dolichometopus productus.*

Dolichometopus productus occurs in the Ute formation about 100 feet higher in 1 of the Blacksmith Fork section.

Formation and locality.—Middle Cambrian: (57g, 57u) Stephen formation; about 1,700 feet (518 m.) above the Lower Cambrian and 3,250 feet (991 m.) below the Upper Cambrian, in the calcareous shales forming *2d* of the Stephen formation,[2] on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen, on the Continental Divide between British Columbia and Alberta; (14s) near the base of the *Ogygopsis* zone of the Stephen formation, just east of the great "fossil bed" on the northwest slope of Mount Stephen, above Field, on the Canadian Pacific Railroad, British Columbia; (58m) about 1,000 feet (305 m.) above the top of the Lower Cambrian in bluish-black and gray limestone (138 feet) of the Stephen formation, Castle Mountain section; northeast slope of Castle Mountain, facing amphitheater, north of Canadian Pacific Railway, Alberta; and (61r′) formation unknown; from a block on

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 198. List under 1*a* and 1*b*.

[2] Idem, Cambrian sections of the Cordilleran area, p. 211.

Moose Pass, between Moose River and Calumet Creek, 10 miles (16.1 km.) east-northeast of the summit of Robson Peak, northwest of Yellowhead Pass, Robson Park, British Columbia, all in Canada.

DOLICHOMETOPUS (?) DEOIS Walcott

Plate 54, figs. 1, 1*a-m*, 2

Dolichometopus deois WALCOTT, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 94. (Described and discussed as a new species essentially as below.)

Bathyuriscus asiaticus LORENZ, 1906, Zeits. deuts. geol. Gesells., Vol. 58, Pt. 2, p. 73, pl. 5, figs. 1-5. (Species characterized and illustrated)

Amphoton steinmanni LORENZ, 1906, Idem, Vol. 58, Pt. 2, p. 75, pl. 4, figs. 15-17. (Species characterized and illustrated.)

Dolichometopus deois WALCOTT, 1913, Research in China, Vol. 3, p. 216, pl. 21, figs. 13, 13*a-d;* pl. 22, figs. 1, 1*a-h,* 2, 2*a-b*. (Species described as below and correlated with the two preceding species of synonymy.)

This species is represented by the central portions of the cephalon, associated pygidia, hypostomæ and thoracic segments. Glabella and fixed cheeks moderately convex; glabella prominent, moderately convex, and marked by three pairs of rather short, very faintly impressed furrows; the sides of the glabella are subparallel for a short distance near the base and then are gently inclined outward to the rounded front margin; occipital furrow shallow, rounded, and merging into the strong occipital ring; the latter is narrow at sides, broadening rather rapidly to the base of a small, backward-sloping occipital spine; in front the glabella curves rather abruptly downward, giving the anterior portion a convex appearance; dorsal furrow shallow and distinctly defined at sides of glabella.

Fixed cheeks narrow, slightly convex, and sloping posteriorly downward to an elongate postero-lateral limb; in front of the palpebral lobe the cheeks slope abruptly down to the frontal limb; palpebral lobes a little longer than one-third the length of the cephalon; there does not appear to be any definite palpebral ridge; the elevated rim of the palpebral slope lobe approaches closely to the dorsal furrow, where it is merged into the downward slope of the fixed cheek; frontal limb short and slightly convex.

Surface apparently smooth under a strong lens in specimens from some localities, while in others it is minutely punctate. This appears to depend somewhat on the character of the matrix and condition of preservation.

On the anterior portion of a cast of a specimen of the glabella there is indicated a very short fourth furrow close to the antero-lateral angle; the same specimen also shows what is the frontal limb

in other cephala divided into a short frontal limb and a narrow, slightly upturned rim.

The largest cephalon in the collection has a length of 17 mm.

This species differs from the type of the genus, *D. suecicus* Angelin [1852, Ed. 1878, p. 73], in the greater convexity of the glabella, more convex frontal limb, and other minor details of the glabella and fixed cheeks; from *D.* (*?*) *dirce* (pl. 54, fig. 5) it differs in the greater expansion of the glabella in front, and from *D.* (*?*) *derceto* (pl. 54, fig. 4) in the configuration of the frontal limb.

Bathyuriscus asiaticus Lorenz (see pl. 54, figs. 1*d*, 2) is founded on specimens of the cranidium that are more or less flattened by compression. *Amphoton steinmanni* Lorenz was founded on small, convex cranidia. Both forms are abundantly represented among the specimens of *Dolichometopus* (*?*) *deois* both in Shan-tung and Manchuria.

Through the courtesy of Dr. Deecke, of the University of Freiburg, I had the opportunity of directly comparing the specimens of Lorenz with the type specimens of *D.* (*?*) *deois*.

I find in the large series of specimens in our collections that the test is finely punctate as in *Anomocare,* but that in others it is not possible to observe the punctæ. This is especially true of the specimens that have been compressed in the limestone. One of the specimens of the cranidium of this species, described by Lorenz as *Bathyuriscus asiaticus* (see pl. 54, fig. 1*d*), shows both smooth and punctate surface, according to the condition of preservation.

Formation and locality.—Middle Cambrian: (C1 and C2) Lower shale member of the Kiu-lung group,[1] 2 miles (3.2 km.) south of Yen-chuang, Sin-t'ai district, and (C4) limestone nodules at the base of the lower shale member of the Kiu-lung group,[2] 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai district, Shan-tung, China.

Also from locality C19, uppermost layers of the Ch'ang-hia limestone,[3] at Ch'ang-hia, Shan-tung, China.

Also from locality C57, limestone nodules in the lower shale member of the Kiu-lung group,[4] 3 miles (4.8 km.) south of Kao-

[1] Blackwelder, Research in China, Pub. No. 54, Carnegie Inst. of Washington, Vol. 1, Pt. 1, 1907, pp. 37 and 40 (part of the third list of fossils), and fig. 10 (beds 4 and 5), p. 38.

[2] Idem, second list of fossils.

[3] Idem, p. 33 (part of last list of fossils).

[4] Idem, pp. 37 and 40 (first list of fossils).

kia-p'u, and 4 miles (6.4 km.) north of Sin-t'ai-hién, Sin-t'ai district, Shan-tung, China.

Also from localities: (35 o) Fu-chóu series, shales about 130 feet (40 m.) above the white quartzite [1] collected in drainage cuts a short distance back from the bluff forming the shore of Tschang-hsing-tau Island; (35p) shales about 80 feet (24 m.) above the white quartzite,[1] and (35r) limestones near the base of the series just above the white quartzite,[1] the latter two collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

DOLICHOMETOPUS (?) DERCETO Walcott

Plate 54, figs. 4, 4*a*

Dolichometopus derceto WALCOTT, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 95. (Described as a new species as below.)

Dolichometopus derceto WALCOTT, 1913, Research in China, Vol. 3, p. 217, pl. 22, figs. 4, 4*a*. (Described and illustrated.)

This species is known only by the central portions of the cephalon, exclusive of the free cheeks. Glabella moderately convex and expanding slightly in width from the base to the rounded front; the surface is marked by two pairs of rather strong, short furrows opposite the palpebral lobe; occipital furrow strong and rather deep; occipital ring narrow at the sides, rising and widening to form the base for a small, sharp occipital spine; dorsal furrow strong on the sides of the glabella.

Fixed cheeks narrow, convex; palpebral lobe narrow, elongate, almost touching the dorsal furrow in front; postero-lateral limb of medium length, marked by a strong furrow parallel to the posterior margin; frontal limb narrow, slightly concave, and almost concealed by the overhanging, almost tumid frontal portion of the glabella.

Surface smooth under a strong lens.

The largest of the three cephala representing this species has a length of 7 mm., exclusive of the occipital spine.

Formation and locality.—Middle Cambrian: (C1 and C2) Lower shale of the Kiu-lung group,[2] 2 miles (3.2 km.) south of Yen-chuang, Sin-t'ai district, Shan-tung, China.

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[1] Blackwelder, Research in China, Pub. No. 54, Carnegie Inst. of Washington, Vol. 1, Pt. 1, 1907, p. 92, for general section giving stratigraphic relations.

[2] Idem, pp. 37 and 40 (part of the third list of fossils), and fig. 10 (beds 4 and 5), p. 38.

DOLICHOMETOPUS (?) DIRCE Walcott

Plate 54, figs. 5, 5*a-b*

Dolichometopus dirce WALCOTT, 1905, Proc. U. S. Nat. Museum, Vol. 29, p. 96. (Characterized as a new species as below.)

Dolichometopus dirce WALCOTT, 1913, Research in China, Vol. 3, p. 218, pl. 22, figs. 5, 5*a-b*. (Described and illustrated.)

Only the central portions of the cephalon of this species are known. It differs from *D.* (?) *deois* (pl. 54, fig. 1) in the nearly parallel sides of the glabella, the absence of glabellar furrows, and the very short, almost flat, frontal limb. The occipital lobe is nearly one-half the length of the cephalon.

Surface under strong magnifier smooth.

The type specimen of the cephalon has a length of 11 mm.

Formation and locality.—Middle Cambrian: (C24) Near top of black oolite group in the uppermost layers of the Ch'ang-hia formation,[1] 2 miles (3.2 km.) east of Ch'ang-hia, Shan-tung, China.

DOLICHOMETOPUS ? EXPANSUS (Walcott)

Plate 53, figs. 5, 5*a*

Dicellocephalus ? expansus WALCOTT, 1884, Monogr. U. S. Geol. Survey, Vol. 8, p. 45, pl. 9, fig. 19. (Description and illustration of cranidium.)

Dicellocephalus ? quadriceps Hall and Whitfield, WALCOTT, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 45, pl. 9, fig. 24. (Describes occurrence of species and illustrates a cranidium distorted by longitudinal compression.)

Dicellocephalus (?) *expansus* MATTHEW, 1893, Trans. Royal Soc. Canada, Vol. 10, Sec. 4, p. 11, footnote. (Considers generic reference as doubtful.)

Dolichometopus expansus (WALCOTT), 1914, Smithsonian Misc. Coll., Vol. 57, p. 350. (Change of generic reference of species.)

Original description.[2]—Glabella elongate subquadrangular or subclavate, the base about one-fifth narrower than the front; surface convex and without perceptible furrows; occipital furrow distinctly defined; occipital ring strong with a small spine on the center of the posterior portion; dorsal furrows well defined along the sides of the glabella; fixed cheeks of medium width, palpebral lobes unknown; an ocular (?) ridge crosses the anterior portion of the right fixed cheek so as to indicate a moderate sized eye lobe between it and the postero-lateral limb; frontal limb as a narrow rim; postero-lateral

[1] Blackwelder, Research in China, Pub. No. 54, Carnegie Inst. of Washington, Vol. 1, Pt. 1, 1907, p. 33 (part of last list of fossils).

[2] Walcott, Monographs U. S. Geological Survey, Vol. 8, 1884, pp. 45-46.

limbs rather narrow, extended and marked by a strong furrow within the posterior margin.

Surface finely punctate.

Observations.—The generic reference is not entirely satisfactory, but with only the cranidium for comparison, I think we may place it with *Dolichometopus* until further data are obtained. The presence of a small occipital spine seems to be indicated by a circular break in the test, but this may be deceptive. A similar break occurs on a specimen of *D. boccar,* but we know from an unbroken specimen that only a minute node has been broken away.

The specimen of *D. ? expansus* occurs in a compact limestone. It was associated with:

Billingsella whitfieldi (Walcott)
Orusia ? eurekensis (Walcott)
Orusia lenticularis (Wahlenberg)
Stenotheca elongata Walcott
Agnostus bidens Meek
Zacanthoides spinosus Walcott

Formation and locality.—Middle Cambrian: (55b) Eldorado limestone;[1] near summit of west side of Secret Canyon, Eureka District [Hague, 1892, Atlas], Eureka County, Nevada.

DOLICHOMETOPUS PRODUCTUS (Hall and Whitfield)

Plate 53, figs. 2, *2a-e,* 3, *3a-b,* 4, *4a*

Ogygia producta Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Parallel, Vol. 4, p. 244, pl. 2, figs. 31-34. (Original description and illustration of species.)

Ogygia parabola Hall and Whitfield, 1877, Idem, p. 245, pl. 2, fig. 35. (Describes and illustrates a pygidium which was referred to *Bathyuriscus productus* (Hall and Whitfield) by Walcott in 1886.)

Niobe producta Brögger, 1886, Om alderen af *Olenellus* zone i Nordamerika, p. 211. (Refers species to genus *Niobe.*)

Bathyuriscus productus Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, p. 217, pl. 30, figs. 1, *1a-i* (in part). (Describes and illustrates species. The specimens illustrated by figs. 1, *1a-b, 1g,* and *1h* are now referred to *Dolichometopus anax.*)

Bathyuriscus productus Miller, 1889, North American Geol. and Pal., p. 533, text fig. 972. (Brief description and 1 figure copied from Walcott.)

Bathyuriscus productus Pack, 1906, Jour. Geol., Vol. 14, p. 297, pl. 2, figs. 3, *3a-b.* (Mentions occurrence of species in "Pioche" Mountain and illustrates a cranidium and two pygidia.)

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[1] Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, p. 184.

Bathyuriscus productus GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 287, fig. 1591. (Brief description and figure of cranidium and pygidium after Walcott.)

The head and pygidium of this species are much like those of the type species of *Dolichometopus, D. suecicus.* The thorax has seven segments, the pleuræ of which have a rather strong furrow that extends from the anterior inner side diagonally across the segment ending about midway where it begins to curve backward to its rather sharp falcate termination.

Specimens of the dorsal shield from the type locality vary from 50 to 60 mm. in length, and cranidia from the Pioche Mountains, Nevada, indicate a length of 75 mm.

The species has a wide geographic distribution and occurs in a variety of rocks. The type specimens are from a very finely arenaceous, Middle Cambrian shale found in East Canyon, Oquirrh Range, Utah. They are compressed and flattened in the shale, but a fairly good conception of the species may be obtained from them. The specimens from the Chisholm shale near Pioche, Nevada, are somewhat better preserved, but they do not retain the original test, and the surface markings are lost with the exception of the fine striæ on the surface of the doublure of the pygidium.

Another interesting locality is at the north end of the McDowell Mountains at River Bed Station, where a form closely allied to this occurs in a limestone. It was identified as *Bathyurellus wheeleri,*[1] but the head is that of *Dolichometopus* and it has the thorax and pygidium of the character of that of *D. productus* as it appears when not flattened in shale.

The species is represented in the Bright Angel arenaceous shales of the Grand Canyon, Arizona, by a number of entire dorsal shields (pl. 53, figs. 4, 4*a*). These appear to have the elongate palpebral lobe and relatively narrow glabella of specimens from the type locality, and the thorax and pygidium are essentially the same.

The specimens from the southern Appalachians are preserved in argillaceous and siliceous shales and limestone. As far as the material available affords the means for comparison, they appear to belong with *D. productus* or a closely related species. A broken specimen from a siliceous shale (locality 10) has seven thoracic segments, and entire associated cranidia and pygidia appear to be similar to the specimens in the shales of the type locality of the species. The specimens in the limestone (locality 14) are strongly convex.

[1] Geog. and Geol., Expl. West 100th Meridian, Vol. 3, 1875, p. 181.

Dolichometopus productus differs from *D. boccar* (pl. 52) in the more anterior position of the palpebral lobes in relation to the length of the glabella, but in the thorax and pygidium they are very closely related.

For a long time I considered *D. productus* as a typical form of *Bathyuriscus,* but with the present study of all the material the species is referred to *Dolichometopus.* (See notes under the latter genus.)

Formation and locality.—Middle Cambrian: (329e, locality of type specimens) Shales in East Canyon above Ophir City, and (3c) about 75 feet (22.9 m.) above the quartzitic sandstones of the Cambrian at Ophir City, west side of Oquirrh Range; also (152c) limestone at north end of McDowell Mountains, River Bed Station, Old State Road; (11s) shales just above Simpson Spring, about 20 miles (32.2 km.) west-southwest of Vernon, on the stage road from Vernon to Fish Spring; and (3f) siliceous shales above concretionary limestone, Onaqui Mountains, 10 miles (16.1 km.) southwest of Grantsville; all five in Tooele County, Utah; also (3v) Chisholm formation, pinkish argillaceous shale, 5.5 miles (8.8 km.) west of Antelope Springs, in Dome Canyon, on road west over the House Range, Millard County; and (30f) Howell formation about 330 feet (101 m.) above the Lower Cambrian, in bluish-black, massive limestone forming 1*f* of the Howell formation; on east side of Dome Canyon, about 1.5 miles (2.4 km.) from its mouth, and five-sixths of a mile (1.33 km.) west of Antelope Springs; also (31s) Howell formation, about 490 feet (149.4 m.) above the Lower Cambrian in limestone interbedded in pinkish argillaceous shale forming 1*d* of the Howell formation; south side of Dome Canyon, about 1 mile (1.6 km.) below the divide and 3 miles (4.8 km.) west-southwest of Antelope Springs (localities 3v, 30f, 31s are all in Millard County, Utah); and (31) Chisholm shale at the Chisholm Mine, southwest slope of Ely Mountains, 3 miles (4.8 km.) northwest of Pioche, Lincoln County, Nevada; also (74e) Bright Angel shale 100 feet (32 m.) above Tapeats sandstone; on west side of Cameron trail, about 0.5 mile (0.8 km.) north of Indian Garden Spring; south side Grand Canyon of the Colorado River, Coconino County, Arizona.

Also (9) Rome formation, shaly sandstone on southeastern slope of ridge 1 mile (1.6 km.) north of the northwest corner of Harlan Knob, about 4 miles (6.4 km.) northeast of Rogersville [see Keith, 1905, areal geology sheet], Hawkins County; and (10) drab shales, western end of Shooks Gap, in Bays Mountains, 10 miles (16.1 km.)

southeast of Knoxville, Knox County; both in Tennessee; (14) Conasauga formation, limestones overlying the sandstones of the Rome formation, near the wagon road and in a quarry near the railroad track, 7 miles (11.2 km.) southwest of Rome [see Hayes, 1902, historical geology sheet], and (142a) railroad cut on west side of Big Cedar Bridge, 3 miles (4.8 km.) northeast of Cave Spring, both in Floyd County, Georgia.

DOLICHOMETOPUS SUECICUS Angelin

Plate 50, figs. 3, *3a-b*, 4, *4a*

Dolichometopus svecicus Angelin, 1852 [Reprint 1854, 1878], Pal. Scandinavica, 1st ed., Lipsiæ, p. 73, pl. 37, fig. 9. (Original description and illustration.)

Dolichometopus suecicus Linnarsson, 1873, Geol. Fören. Stockholm Förhandl., Vol. 1, No. 13, p. 246. (Refers to occurrence of species.)

Dolichometopus suecicus Brögger, 1878, Nyt Mag. for Naturvid., Vol. 24, p. 46, pl. 3, fig. 12. (Notes occurrence of species at Krekling and illustrates a cranidium and pygidium.)

Dolichometopus suecicus Matthew, 1897, Trans. Royal Soc. Canada, 2d ser., Vol. 3, Sec. 4, pp. 184, 185, pl. 3, figs. *7a, 7b*. (Reproduces top view and side outline of a drawing of the type cranidium of the species.)

Dolichometopus suecicus Lorenz, 1906, Zeits. deuts. geol. Gesells., Vol. 58, Pt. 1, p. 74, text fig. (Compares *Dolichometopus* and *Bathyuriscus* and illustrates *D. svecicus* Angelin.)

Of this species only the cranidium and associated pygidium are known to me. Now that we have several species of *Dolichometopus* represented by the entire dorsal shield, there is little, if any, doubt that the pygidium is correctly referred to the species. Dr. Matthew has illustrated the type specimen,[1] (pl. 50, fig. 4) and in this paper I am illustrating the cranidium and pygidium as found in the Andrarum limestone at Andrarum. The largest cranidium has a length of 21 mm.

Surface of test punctate and when not worn smooth marked by fine, sharp, irregular, inosculating ridges, those on the glabella more or less concentric in relation to the central portion and on the occipital ring subparallel to the posterior margin.

By reflected light traces of three pairs of glabellar furrows may be seen, and the matrix of the test of the glabella shows slight impressions of glabellar furrows.

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 3, 1897, Sec. 4, pl. 3, figs. *7a, 7b*.

Formation and locality.—Middle Cambrian: (8w) Andrarum limestone; *Paradoxides forchhammeri* zone, at Andrarum, 20 miles (32.2 km.) northwest of Simrishamn, Province of Christianstad, Sweden.

DOLICHOMETOPUS TONTOENSIS, new species

Plate 51, figs. 1, 1*a-h*

This fine species I found in the upper beds of the Tonto sandstone in 1882 in the form of casts in a hard sandstone. Entire specimens were first collected and presented to the United States National Museum in 1911 by Mr. Niles J. Cameron, of Grand Canyon, Arizona. The latter are compressed in a greenish, very fine arenaceous shale, but do not retain the outer test.

The species differs from *D. productus* (pl. 53) in having a smaller palpebral lobe, a median spine on each thoracic segment and the anchylosed segments of the axial lobe of the pygidium, also in the enlargement of the fifth thoracic segment. This character is present in the 13 specimens preserving the thorax, and is not present in the 11 associated specimens of *D. productus*. This species also attains a larger size than any other of the genus. One entire dorsal shield has a length of 97 mm., and an associated pygidium indicates that specimens existed of 110 mm. in length. The next largest species, as far as known, is *D. bion* (pl. 52, fig. 2*b*).

The combination of small eye lobe, median spine on thoracic segments and enlarged fifth thoracic segment, suggests a reversion to primitive characters in this species that might be recognized by a subgeneric name if further investigation justifies it.

At locality 74 this species is associated with the following fauna in a brownish-weathering, bedded sandstone:

Micromitra pealei (Walcott)
Micromitra (*Paterina*) *crenistria* (Walcott)
Micromitra (*Paterina*) *superba* (Walcott)
Micromitra (*Iphidella*) *pannula* (White)
Obolus zetus (Walcott)
Obolus (*Westonia*) *chuarensis* (Walcott)
Obolus (*Westonia*) *euglyphus* (Walcott)
Lingulella lineolata (Walcott)
Lingulella perattenuata (Whitfield)
Billingsella obscura Walcott
Alokistocare althea Walcott

In the arenaceous shale of locality 74e (about 100-120 feet above the horizon of locality 74) I found

Obolus (*Westonia*) *chuarensis* Walcott
Eocystites ? undt. species
Hyolithes
Alokistocare althea Walcott
Dolichometopus productus (Hall and Whitfield)
Dolichometopus tontoensis Walcott

Formation and locality.—Middle Cambrian: (74e) Bright Angel shale 100 feet (32 m.) above Tapeats sandstone. On west side of Cameron trail about 0.5 mile (0.8 km.) north of Indian Garden Spring, south side Grand Canyon of Colorado River, Coconino County; and (74) Tapeats sandstone; about 300 feet (91.4 m.) above its base, at the head of Nunkoweap Valley, Grand Canyon of the Colorado River, both in Arizona.

HOUSIA, new subgenus

This form is distinguished from *Dolichometopus* by its small palpebral lobe, absence of genal spine on free cheek, form of termination of pleural lobe of thoracic segments, and outline of normal form of pygidium. Surface unknown. Fragments of the only species referred to *Housia* indicate a length of 7.5 to 8 cm.

Genotype.—*Dolichometopus* (*Housia*) *varro* Walcott.

The one species now referred to *Housia* is from the central portion of the Upper Cambrian in the House Range of western Utah.

DOLICHOMETOPUS (HOUSIA) VARRO, new species

Plate 65, figs. 1, 1*a-e*

The general characters of this species have been given in connection with the subgenus *Housia*. Only one specimen of the cranidium was found, although 11 free cheeks and five pygidia were collected. That it was a fairly large species is shown by a thoracic segment 40 mm. in length and several large free cheeks.

Formation and locality.—Upper Cambrian: (30 l) Orr formation; about 2,790 feet (860 m.) above the Middle Cambrian and 1,900 feet (579.1 m.) below the top of the Upper Cambrian, in shales forming 1*b* of the Orr formation [1] on Orr Ridge, about 5 miles (8 km.) south of Marjum Pass; also (30y) in slightly metamorphosed shales sup-

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 176.

posed to be the equivalent of 1*b* of the Orr Ridge section above the granite contact on top of the ridge north of Notch Peak, both in House Range, Millard County, Utah.

Family Asaphidæ Burmeister

Subfamily Ogygiocarinæ Raymond

. Ogygiocarinæ Raymond, 1913, Zittel-Eastman's Paleontology, p. 718.

Opisthoparia with large subequal cephalon and pygidium, prominent eyes, palpebral (ocular) ridge crossing free cheeks, thorax with 7 to 11 segments.

Hypostoma rounded. Middle Cambrian to Ordovician.

Dr. Raymond has included *Megalaspis* and other genera of a similar character under Ogygiocarinæ, but with our present information I am inclined to include only *Ogygiocaris* Angelin, *Ogygopsis* Walcott, *Orria* Walcott, *Asaphiscus* Meek, and *Blountia* and *Maryvillia* are provisionally referred to the subfamily.

Genus OGYGOPSIS Walcott

Ogygopsis Walcott, 1888, Proc. U. S. Nat. Mus., Vol. 11, p. 446. (Names *Ogygia klotzi* Rominger as genotype of genus.)

Ogygopsis Miller, 1892, North American Geol. and Pal., First Appendix to 1889 Ed., p. 710. (Brief note on genus.)

Ogygopsis Grabau and Shimer, 1910, North American Index Fos., Vol. 2, p. 289. (Brief description of genus.)

Ogygopsis Raymond, 1912, Trans. Roy. Soc. Canada, 3d ser., Vol. 5, Sec. 4, p. 116. (Discusses development and relationship of genus.)

Dorsal shield elongate-elliptical in outline; axial lobe distinct; pleural lobes broad. Cephalon shorter and broader than the pygidium, semicircular in outline with genal angles produced into short spines. The facial sutures cut the posterior border just within the genal angles and extend inward and forward with a slight sigmoid curve to the base of the eye; arching over the eye lobes they curve gently outward and then inward to the frontal border, which they cut across obliquely inward; the outer border is rather narrow in front of the glabella and of medium width on the free cheeks; the posterior border is narrow and separated by a strong furrow from the body of the fixed cheeks.

Cranidium with a large glabella; large free cheeks and strong postero-lateral limbs; glabella nearly as long as the cranidium, slightly widened towards the front: moderately convex and marked by a

pair of strong postero-lateral furrows and three pairs of faint, short furrows, the posterior two pairs of which extend obliquely inward and backward, while the two anterior pairs extend inward and slightly forward; occipital ring smooth, rather strong and with a well-defined occipital furrow separating it from the glabella. Fixed cheeks of narrow to medium width; postero- and antero-lateral limbs broad; palpebral lobes small. Free cheeks large, broad, and marked by strong venation radiating from the base of the eye lobe outward to the outer border.

Thorax with eight segments; axial lobe narrow, each segment marked by a small, sharp median node situated on a slight forward-arching fold of the surface near the posterior margin; pleural lobes wide and rather flat; pleural furrows strong; they extend across from the anterior, inner side of the pleura to the outer posterior side.

Pygidium large, with a distinct axial lobe divided into eight or more rings that are continued out onto the broad pleural lobes as broad, shallow furrows separated by narrow ridges; the furrows terminate just within a narrow border.

Surface of exterior test marked by a very fine shallow pitting.

Genotype.—*Ogygia klotzi* Rominger [1887, Proc. Acad. Nat. Sci. Phil., p. 12, pl. 1, fig. 1].

Stratigraphic range.—*Ogygopsis klotzi* occurs in the Stephen formation of the Middle Cambrian about 3,000 feet below the Upper Cambrian and 2,000 feet above the Lower Cambrian.

Geographic distribution.—This is a Cordilleran genus as far as known. *Ogygopsis klotzi* occurs at Mount Stephen in eastern British Columbia on the line of the Canadian Pacific Railway, also in the Wasatch Range of northern Utah.

Observations.—*Ogygopsis* recalls at once *Ogygiocaris* Angelin, as represented by *Ogygiocaris dilitata* (Brunn) and *O. buchii* (Brongniart). The most marked differences between the two genera are in the presence of well-defined palpebral (ocular) ridges on the fixed cheeks of *Ogygopsis,* and in general, the more primitive character of the glabella and cephalon.

The genus *Orria* differs from *Ogygopsis* in the almost entire absence of fixed cheeks, large palpebral lobes, very narrow postero-lateral limbs, broad, straight pleural furrows and shorter axial lobe of pygidium.

Both *Ogygopsis* and *Orria* foreshadow in the Middle Cambrian time the Lower Ordovician genera of the Ogygiocarinæ, *Ogygopsis* being nearer to *Ogygiocaris* than *Orria.*

OGYGOPSIS KLOTZI (Rominger)

Plate 66, figs. 1, 1*a-b*

Ogygia klotzi ROMINGER, 1887, Proc. Acad. Nat. Sci., Phil., p. 12, pl. 1, fig. 1. (Describes and illustrates species.)

Ogygia ? klotzi WALCOTT, 1888, American Jour. Sci., 3d ser., Vol. 36, p. 166. (Notes difference between this species and typical forms of *Ogygia*.)

Ogygopsis klotzi WALCOTT, 1889, Proc. U. S. Nat. Mus., Vol. 11, p. 446. (Proposes *Ogygopsis* with *Ogygia klotzi* as the genotype.)

Ogygia (*Ogygopsis*) *klotzi* MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, Sec. 4, p. 58. (Describes species and supposed young of same.)

Ogygopsis klotzi WOODWARD, 1902, Geol. Mag., Dec. 4, Vol. 9, p. 530, text fig. 1. (Describes and discusses species and its relations to other genera. Gives outline figure.)

Ogygopsis klotzi WALCOTT, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 4, fig. 4. (Illustrates entire dorsal shield.)

Ogygopsis klotzi GRABAU and SHIMER, 1910, North American Index Fos., Vol. 2, p. 289, fig. 1597. (Description and reproduction of Walcott's figure of 1908.)

The characters of this species have been given in the description of the genus *Ogygopsis*. There is no closely related Cambrian species with which it may be compared. *Orria elegans* of the Middle Cambrian has a somewhat similar pygidium, but the differences in the thoracic pleural furrows, fixed cheeks, and palpebral lobes are of generic value.

The nearest Ordovician form appears to be *Ogygiocaris buchii* (Brongniart),[1] from which it differs in its glabella, palpebral lobes, presence of palpebral (ocular) ridge on fixed cheeks, and axial lobe of thorax and pygidium.

Ogygopsis klotzi is the most abundant fossil at the Mount Stephen locality, and hundreds of specimens of the dorsal shield without the free cheeks have been collected. The vertical range of the species in the Stephen formation is about 200 feet (60 m.). Its vertical range at locality 55e in Utah as far as known is only a few feet. The very limited geographic range of the species in British Columbia is most noticeable, and it is limited so far as known to one other locality in Utah.

Dimensions.—The largest dorsal shield in the collection has a length of 11 cm.

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[1] Monogr. British Trilobites, Salter, Pal. Soc., 1864-1883, p. 125, pls. 14, 15.

Matthew describes two small specimens of the dorsal shield as follows:[1]

. . . . In the 11 mm. tests (one-tenth of the length of the adult) there are tubercles on the thoracic rings for the attachment of spines; in one example these spines are attached to back of the rings; that of the occipital ring crosses two joints of the thorax, and that on the last joint of the thorax crosses three rings of the pygidium. In the adult all these spines have disappeared except that the fifth joint is sometimes seen to have a short spine. In the young shields the geniculation of the pleuræ, and the relief of the rachis are more pronounced than in the adult.

In the 11 mm. test there are eight joints in the thorax and 10 in the pygidium, and eight costæ on the side lobes of the latter. At this age, then, the species had the full number of joints in the thorax, but lacked two of the full number in the pygidium. Tests of 22 mm. length had an additional joint in the pygidium, and in tests 35 mm. long, the full number was attained.

A difference from the adult is observable in the length of the eye lobe of the young: in these the proportion between the length of the anterior extension of the suture of the eye lobe, and of the posterior extension are respectively 1, 1, 2; in the adult it is 1½, 1, 2½ or 3. This contraction of the eye lobe is in accordance with what has been observed in other genera, *e. g. Paradoxides.*

I find that the minute spine or tubercle is almost invariably crushed and left in the matrix, so that all that remains is the small base on the transversely lined or corrugated posterior part of the axial portion of the thoracic segment.

From Dr. Matthew's description of the spines on the 11 mm. specimen, it may be that he had a young specimen of *Neolenus serratus* or *Zacanthoides spinosus,* which are very abundant in association with *O. klotzi.*

Formation and locality.—Middle Cambrian: (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (707 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian; at the great "fossil bed" on the northwest slope of Mount Stephen; and (58r) about 2,200 feet (676.9 m.) above the Lower Cambrian, and 3,725 feet (1,146 m.) below the Upper Cambrian, in the limestones forming 2 of the Stephen formation, in the amphitheater between Mounts Stephen and Dennis, both localities above Field on the Canadian Pacific Railway, British Columbia, Canada.

Also (55e) Spence shale horizon of the Ute formation; about 100 feet (30.5 m.) above the Brigham quartzite, at the mouth of the first small canyon south of Wasatch Canyon, east of Lakeview Ranch, 5 miles (8 km.) north of Brigham, Boxelder County, Utah.

[1] Trans. Roy. Soc. Canada, 2d ser., Vol. 5, Sec. 4, 1899, p. 58. Specimens in Museum of University of Toronto, Canada.

ORRIA, new genus

General form elliptical, moderately convex. Cephalon semicircular with a border of medium width terminating at the genal angles in a short spine; the glabella widens very slightly towards the front and is marked by a distinct pair of oblique posterior furrows that are connected by a very shallow transverse furrow; second pair of furrows short and extending less obliquely backward onto the glabella; third pair short and nearly at right angles to the side of the glabella; fourth and anterior pair extending inward and a little forward;[1] occipital ring of medium width and marked on the posterior side by a narrow band that is broadest at the center and sloping away at the sides; it has the appearance of a crowding forward of transverse lines toward the base of the small tubercle; a minute, sharp-pointed tubercle occurs at the front center margin of this band which is also marked by irregular raised lines subparallel to the front margin of the band. A similar band and tubercle occurs on each of the thoracic segments and the anchylosed segments of the pygidium. Fixed cheeks little more than a line between the glabella and rather large palpebral lobes; they merge posteriorly into narrow lateral limbs that extend out beyond the line of the termination of the thoracic segments; each limb has a broad, shallow intramarginal furrow that occupies nearly all of its surface; anteriorly the fixed cheek is very narrow and curves forward to merge into a very narrow frontal border in advance of the glabella; palpebral lobes a little less than one-third the length of the cranidium; the raised outer margin extends anteriorly across the very narrow space between the anterior end of the eye lobe and the glabella, and thus forms a very short palpebral (ocular) ridge.

Free cheeks large and rising gradually from the groove within the outer border to the base of the elongate, narrow eye lobe; their most marked character is the system of strong, irregular inosculating ridges that radiate from the base of the eye outward to the intramarginal furrow.

Thorax with nine transverse segments that are all of nearly the same transverse length; axial lobe convex and marked by a minute median tubercle as described above in connection with the occipital ring; pleural lobes nearly flat with each segment terminating abruptly, the postero-lateral edge having a very short, blunt spine; pleural furrows broad and occupying nearly the entire width of the

[1] The glabella is very much like that of *Bathyuriscus*, see plate 46.

segment from the central axis out to its blunt termination at the end of the segment.

Pygidium large, border very narrow; axial lobe convex, about two-thirds the length of the pygidium, and divided into seven rings and a terminal section; the rings are similar to those of the axial lobe of the thorax and have a similar band and central tubercle; the pleural lobes are broad and marked by eight broad, shallow furrows and a posterior pair that appear to come out of the posterior section of the axis; each broad furrow is separated from those adjoining by two narrow, sharp ridges with a narrow furrow between them that represents the anchylosed line of separation of the original segmentation now united to form the pygidium.

Surface minutely granular; the venation on the free cheeks and the lines on the axial lobe of the thorax and pygidium have been characterized above.

Genotype.—Orria elegans Walcott.

Dimensions.—The largest dorsal shield of the genus as now known has a length of 7 cm. A large pygidium indicates that the individual to which it belonged was at least 9 cm. in length.

Stratigraphic and geographic range.—The one known species occurs in the Middle Cambrian Marjum formation in western Utah.

Observations.—Orria is an *Ogygopsis*-like form that differs from the latter in several marked characters.

1. The cephalon is smaller in proportion to the thorax and pygidium. (a) Fixed cheeks nearly absent between palpebral lobes and glabella; (b) palpebral lobes large and close to glabella; postero-lateral limbs long and narrow; antero-lateral limbs only a narrow space between the gabella and facial sutures; facial sutures accord with differences in fixed cheeks and limbs.

2. Pleural furrows of thoracic segments broad and straight instead of narrow and diagonal.

3. Median axis about two-thirds the length of the pygidium.

The relation of *Orria* to other genera of the Ogygiocarinæ is not any nearer than to *Ogygopsis*. Its relatively smaller cephalon, large palpebral lobes, and narrow fixed cheeks suggest *Ogygiocaris buchii* (Brongniart), but the pleural furrows and axial lobe of pygidium are quite distinct.

The resemblance between the cephalon of *Orria* and *Bathyuriscus* (pl. 46) indicates that they originated from a similar ancestral type. Both *Orria* and *Ogygopsis* suggest a stage of development between *Bathyuriscus* and *Ogygiocaris*.

ORRIA ELEGANS, new species

Plate 66, figs. 2, *2a-b*

The characters of this species are given in the description of the genus *Orria,* and there is no other species of the genus with which to compare it. Two nearly entire dorsal shields and many fragments were collected from the dark shaly limestone forming 1*c* of the Marjum formation.[1] The associated fauna, which is listed under description of *Marjumia typa* (p. 402), is large and varied and indicates a most favorable environment for the development and growth of large trilobites.

Formation and locality.—Middle Cambrian: (11 q) Marjum formation; about 2,300 feet (707 m.) above the Lower Cambrian, and 660 feet (203 m.) below the Upper Cambrian, in the limestone forming 1*c* of the Marjum formation, 2.5 miles (4 km.) east of Antelope Springs, in west face of ridge east of Wheeler amphitheater, House Range, Millard County, Utah.

Genus ASAPHISCUS Meek

Asaphiscus MEEK, 1873, Sixth Ann. Rept. U. S. Geol. Surv. Terr., p. 485, footnote. (Founds genus on *Asaphiscus wheeleri,* then an unpublished species, and comments on genus.)

Asaphiscus WALCOTT, 1875 [1877], Twenty-eighth Rept. N. Y. State Mus. Nat. History, doc. ed., p. 94, footnote. (Considers *Asaphiscus* as similar to *Bathyurus.* This is corrected in 1886.)

Asaphiscus WALCOTT, 1879, Idem, p. 94, footnote. (Repeats preceding reference.)

Asaphiscus WALCOTT, 1886, Bull. U. S. Geol. Surv., No. 30, p. 219. (Gives Meek's description and with comments.)

Asaphiscus MILLER, 1889, North American Geol. and Pal., p. 530. (Meek's description and figure of *A. wheeleri.*)

Asaphiscus GRABAU and SHIMER, 1910, North American Index Fossils, Vol. 2, p. 289. (Brief note and figure of *A. wheeleri.*)

Dorsal shield subelliptical, moderately convex, distinctly trilobed. Cephalon semicircular in outline with genal angles rounded or prolonged into spines of moderate length; border rounded, strong and clearly defined all about the cephalon; glabella subconical in outline, rounded convex and with only slight traces of a pair of oblique posterior lateral furrows and two pairs of short, faint anterior furrows; occipital furrow shallow and only faintly separating the glabella and occipital ring; fixed cheeks about one-half the width of the glabella, posteriorly they merge into a rather large postero-lateral

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 179-180.

limb and anteriorly into the broad frontal limb; palpebral lobe of medium size and located just back of the transverse center of the cranidium. Very slight traces of palpebral ridges crossing the fixed cheeks. The facial sutures cut the posterior margin within the genal angles and extend obliquely inward to the posterior end of the eye lobe, in front of the latter they extend gently outward and incurve across the frontal border. Free cheeks about one-fourth the width of the cephalon; they rise rather rapidly to the base of the narrow eye lobe and may or may not terminate in a genal spine.

Thorax with from 7 to 11 segments; pleuræ with strong longitudinal furrow, and usually short falcate ends. The axial portion of the segment may be smooth or have a central node or small spine.

Pygidium relatively large and with a strong convex axial lobe that is divided into several transverse rings by narrow furrows that are slightly indicated on the pleural lobes by shallow furrows; border usually broad and slightly flattened.

Surface smooth or marked by shallow pits, and rarely it is granulated.

Genotype.—*Asaphiscus wheeleri* Meek.

Stratigraphic range.—Middle Cambrian to Upper Cambrian.

Geographic distribution.—The genus is represented by nine species in the Cordilleran area of Montana, Wyoming, and Utah; two doubtful species in the Appalachian area of Pennsylvania, and one species in Manchuria, China. It may be represented in Europe, but in the preliminary study I have not recognized it.

Observations.—The cranidium of *Asaphiscus* differs from that of *Anomocare* in its shorter, smaller eyes and elongate glabella with well-defined lateral furrows and in form of frontal limb and border. The pygidium of the genotype *Asaphiscus wheeleri* differs from that of the genotype *Anomocare læve* Angelin in having a much longer axial lobe and narrower border, but these characters may be variable in species referred to either genus.

Anomocarella differs from *Asaphiscus* in its shorter, smaller eyes, shorter and broader glabella in proportion to its width at the base, and in its smaller pygidium which has a narrow border.

The cranidium of *Asaphiscus* is not unlike that of *Liostracus*, but the other parts of the dorsal shield differ greatly. *Asaphiscus* has characters that relate it closely to *Ptychoparia*. The cranidium has the same form of glabella, fixed cheeks and palpebral lobes. The pleural furrows do not start away from beside the axial lobe as abruptly as in the genotype of *Ptychoparia, P. striata,* but in other

species it is difficult to indicate any difference of value in the thorax except fewer thoracic segments. The pygidium of *Bathyuriscus* is proportionately larger, and has a broader and flatter border. It is not difficult to grade specimens of *Ptychoparia* that serve to establish a strong connection between the two genera. We now have a number of species represented by cranidia which it is very difficult to assign to either genus without feeling that the discovery of entire specimens may make a new reference necessary.

A group of species that are closely related to each other in form of cephalon, thorax, and less so in pygidium, includes *A.* (?) *capella, A. camma, A. calenus,* and *A. iddingsi.* They all differ from *A. wheeleri* in having strong genal spines on the cephalon, and longer and sharper terminations on the thoracic segments. The pygidium of *A.* (?) *capella* varies most widely from that of *A. wheeleri.*

The small and interesting group of species from the Upper Cambrian Weeks formation of Utah, *A.? minor, A.? granulatus,* and *A.? unispinus* are small in size and they have a strong genal spine that is lacking in the genotype *A. wheeleri.* The variation in the number of thoracic segments, seven to 11, is also unusual. These species and those of the Upper Cambrian of the Appalachian region, *A. ? agatho, A. ? anaxis, A. ? duris,* and *A. ? florus,* all appear to be degenerate descendants of the large *A. wheeleri* type of the Middle Cambrian fauna and all indicate an undetermined genus or subgenus.

The species now referred to *Asaphiscus* are:

Asaphiscus calenus Walcott, Middle Cambrian, Montana (pl. 60, fig. 1).
Asaphiscus camma Walcott, Middle Cambrian, Montana (pl. 60, fig. 2).
Asaphiscus (?) *capella* Walcott, Middle Cambrian, Montana (pl. 59, fig. 2).
Asaphiscus ? granulatus Walcott, Upper Cambrian, Utah (pl. 61, fig. 2).
Asaphiscus iddingsi Walcott, Middle Cambrian, Manchuria, China (pl. 59, fig. 1).
Asaphiscus ? minor Walcott, Upper Cambrian, Utah (pl. 61, fig. 3).
Asaphiscus ? unispinus Walcott, Upper Cambrian, Utah (pl. 61, fig. 1).
Asaphiscus wheeleri Meek, Middle Cambrian, Utah (pl. 58, fig. 1).
Asaphiscus sp. undt. (3), Upper Cambrian, Utah.
Asaphiscus sp. undt. (1), Middle Cambrian, Wyoming.
Asaphiscus ? sp. undt. (2), Upper Cambrian, Tennessee (pl. 63, fig. 3).
Asaphiscus ? agatho Walcott,[1] Upper Cambrian, Pennsylvania; Tennessee (pl. 63, fig. 9).
Asaphiscus ? anaxis Walcott, Upper Cambrian, Pennsylvania (pl. 63, fig. 2).
Asaphiscus calanus Walcott, Middle Cambrian, Virginia (pl. 61, fig. 8).
Asaphiscus ? duris Walcott, Upper Cambrian ?, Pennsylvania (pl. 63, fig. 8).

[1] Arranged alphabetically after dividing into western and eastern series.

Asaphiscus ? florus Walcott, Upper Cambrian ?, Pennsylvania (pl. 63, fig. 6).

Asaphiscus ? cf. *florus* Walcott; Upper Cambrian ?, Pennsylvania (pl. 63, fig. 7).

ASAPHISCUS CALANUS, new species

Plate 61, figs. 8, 8*a*

This species is most nearly related to *Asaphiscus* (*?*) *capella*. It differs in the form of the frontal limb and glabella of the cranidium. The axial lobe of the associated pygidium is also shorter and the border wider. The specimens are preserved as casts in a fine-grained, arenaceous, shaly rock.

Formation and locality.—Middle Cambrian: (47h) Arenaceous shales; Wolf Creek, 6 miles (9.6 km.) below Rocky Gap, Bland County, Virginia.

ASAPHISCUS CALENUS, new species

Plate 60, figs. 1, 1*a-c*

This species at once recalls *A. wheeleri* and *A.* (*?*) *capella*. It differs from the former in the form of the frontal limb and border, glabella, termination of thoracic segments, and form of pygidium. From *A.* (*?*) *capella* it is distinguished by its pygidium and minor details of the cephalon. It is more nearly related to *A. camma*, but differs in the relative width of the frontal limb and border, shorter eye lobes, and in having a less transverse pygidium.

The largest dorsal shield in the collection has a length of 43 mm. and nine thoracic segments.

Formation and locality.—Middle Cambrian: (5f) Wolsey shale: in Meagher County on the road to Wolsey, about 4 miles (6.4 km.) south of the divide at the head of Sawmill Creek, and 11 miles (17.7 km.) south of Neihart, Little Belt Mountains quadrangle (U. S. G. S.), and (62j) upper portion of Wolsey shale below Meagher limestone; 2 miles (3.2 km.) east of Logan, on north side of Gallatin River, Gallatin County, Montana.

ASAPHISCUS CAMMA, new species

Plate 60, figs. 2, 2*a-c*

This species is characterized by its relatively long eye lobes, broader glabella, and narrower frontal border, when compared with *A.* (*?*) *capella* and *A. calenus*. Its pygidium is more transverse than that of

those species or of *A. iddingsi*. It also has 10 segments in the thorax and the related species have nine.

The largest pygidium in the collection has a length of 15 mm., which indicates a length of 50 mm. for the dorsal shield to which it belonged.

Formation and locality.—Middle Cambrian: (4g) Wolsey shale; 5 miles (8 km.) east-northeast of Logan and 1 mile (1.6 km.) north of junction of East and West Gallatin Rivers [Three Forks sheet (U. S. G. S.)], Gallatin County, Montana.

ASAPHISCUS (?) CAPELLA, new species

Plate 59, figs. 2, *2a-c*

The cephalon and thorax of this species are much like the same parts in *A. wheeleri* except that *A. (?) capella* has genal spines on the free cheeks and a more distinctly concave frontal border. Its pygidium differs decidedly from that of *A. wheeleri* in having a very wide, sloping, and slightly concave border section and doublure, that terminates within a narrow border; a tapering axial lobe that is three-fifths the length of the pygidium is extended across the wide lower slope as a low, rounded ridge that expands towards the posterior margin and merges into it; the seven rings on the axis extend outward and backward across the pleural lobes as slightly rounded, nearly flat segments, that terminate by merging into the narrow border.

The largest dorsal shield has a length of 56 mm., and nine thoracic segments, and a small node at the center of each segment and the occipital ring.

The pygidium, large eyes, and terminations of thoracic segments suggest a different generic reference, but I am not prepared to make it at present.

Formation and locality.—Middle Cambrian: (54z) Wolsey shale; Half Moon Pass, Big Snowy Mountains, Fergus County, Montana.

ASAPHISCUS ? GRANULATUS, new species

Plate 61, figs. 2, *2a*

This species differs from *A. ? minor* in having 10 thoracic segments, a strong median spine on the axial lobe of the ninth segment, and in its granulated surface. The surface of the test is minutely granular with large granules scattered over the cephalon and a row

of about 14 large granules on each thoracic segment and about 10 or less on each of the four anchylosed segments of the pygidium.

The spine on the ninth thoracic segment has a strong base and is extended back over the pygidium.

There are two specimens in the collection; the larger has a length of 23 mm. with two segments crowded under the cephalon, and the other has 10 thoracic segments and the pygidium.

Formation and locality.—Upper Cambrian: (30n) Weeks formation; about 3,750 feet (1,143 m.) above the Lower Cambrian in shales forming 1*c* of the Weeks formation, on the north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

ASAPHISCUS IDDINGSI Walcott

Plate 59, figs. 1, 1*a-b*

Asaphiscus iddingsi Walcott, 1911, Smithsonian Misc. Coll., Vol. 57, No. 4, pp. 99-101, pl. 16, fig. 3. (Described and discussed as a new species essentially as below.)

Asaphiscus iddingsi Walcott, 1913, Research in China, Vol. 3, Cambrian Faunas of China, p. 221, pl. 23, figs. 1, 1*a-b*. (Described as below.)

Dorsal shield longitudinally oval in outline, moderately convex. Cephalon semicircular in outline; a little more than one-third of the entire length of the dorsal shield; bordered by a nearly flat or slightly rounded margin that passes at the genal angle into a moderately strong genal spine; within the genal spine a rounded posterior border is separated from the fixed cheek by a rounded, clearly defined furrow; the intramarginal furrow is shallow and rounded. Cranidium moderately convex and roughly subquadrate in outline; the frontal limb is slightly convex and, with the anterior portion of the glabella and the front margin, forms a gentle slope that is broken only by the slight dorsal furrow in front of the glabella and the shallow intramarginal furrow; the frontal limb merges on the sides into the fixed cheeks, which are a little less than one-half the width of the glabella; posteriorly the fixed cheeks merge into relatively small postero-lateral limbs; palpebral lobe narrow and extended in front as a low ridge that crosses the fixed cheek to the dorsal furrow near the antero-lateral angle of the glabella; that portion of the palpebral lobe above the eye is about one-fourth the length of the cephalon.

Glabella large, slightly narrower in front than at the occipital furrow; sides nearly straight and slightly converging, frontal margin broadly rounded; surface marked by very faint impressions of three

pairs of glabellar furrows, which can only be seen where the surface is very perfectly preserved. Occipital ring about as wide as the frontal margin and separated from the glabella by a shallow furrow that terminates on the side slightly in advance of the posterior intramarginal furrow. Free cheeks about as wide opposite the eye as the fixed cheeks; eye lobe about one-fourth the length of the cephalon. Postero-lateral angle continued backward into a moderately strong spine. The facial sutures cut the posterior margin just within the genal angle and extend obliquely inward with a slightly sigmoid curvature to the base of the eye-lobes; curving over and around the eye-lobes, they pass forward and a little outward, cutting the frontal margin obliquely.

Thorax with nine segments; axial lobe moderately convex, slightly narrower than the pleural lobes in compressed specimens; on the outer side of each segment a low, rounded node or ridge is separated from the main body of the segment by a slightly oblique furrow transverse to the segment; pleural lobes slightly convex, nearly flat out to the geniculation, where they curve slightly downward and backward; each pleura has a well-defined furrow starting near the inner anterior margin and extending backward to the center of the pleura at the geniculation, where it curves slightly backward and terminates on the broadly rounded, slightly falcate end of the pleura.

Pygidium roughly semicircular in outline, one-fourth the length of the dorsal shield; anterior margin nearly transverse at the axial lobe and curving slightly backward to conform to the curvature of the last thoracic segment; axial lobe moderately convex and tapering gradually toward its posterior section, which is just within the nearly flat marginal border; it is divided by four transverse furrows into four rings and a terminal section; three anchylosed pleural segments are outlined on the pleural lobes by furrows that curve backward and terminate on the inner margin of the doublure; this line is continued forward on the pleural lobes of the thorax, terminating on each side opposite the posterior end of the facial suture.

Surface of specimens preserved in the limestone nearly smooth or marked by very minute shallow pits.

Dimensions.—A dorsal shield 30 mm. in length has the following dimensions:

Cephalon:

	mm.
Length	11.0
Length of eye-lobe	3.5
Width at posterior margin	20.0
Width of glabella at posterior margin	6.0

Thorax:

Length	12.0
Width at fourth segment	19.0
Width of axial lobe at first segment	5.5
Width of axial lobe at ninth segment	4.0

Pygidium:

Length	7.0
Width at union with thorax	12.0

Fragments of this species are quite abundant in the limestones and interbedded shales. A few entire specimens are found in a fine argillaceous shale a short distance above the white quartzite at the base of the section, and it is from the best specimens of these that the above description was drawn, together with specimens of the cranidium in the limestone.

In general outline and appearance *Asaphiscus iddingsi* approaches the type of the genus, *A. wheeleri* Meek (p. 390). *Asaphiscus iddingsi* has a genal spine, a longer eye-lobe, a proportionately shorter cephalon, and nine, instead of eight, segments in the thorax.

Formation and locality.—Middle Cambrian: (35r and 36e) Fu-chóu series, shales interbedded with limestones near the base of the series just above the white quartzite [see Blackwelder, Research in China, Vol. 1, Pt. 1, p. 92, for general section giving stratigraphic relations]; collected in a low bluff on the shore of Tschang-hsing-tau Island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

ASAPHISCUS ? MINOR, new species

Plate 61, figs. 3, 3*a-b*

Asaphiscus minor Walcott, 1908, Smithsonian Misc. Coll., Vol. 53, p. 178. (Name listed in fauna of Weeks formation.)

This is a small species with only seven thoracic segments and with rather strong genal spines. It has four rings and a terminal section on the axial lobe of the pygidium and four flat segments on the pleural lobes separated by narrow, shallow furrows.

Surface of test apparently finely granulated. The average length of the dorsal shield is about 14 mm. One has a length of 17 mm. *Asaphiscus ? minor* differs from *A. ? granulatus* and *A. ? unispinus* in having seven thoracic segments and in the absence of a thoracic

spine, and from *A. ? granulatus* in the absence of coarse granulations. It is the most abundant species, as over 60 specimens were found, while only two of *A. ? granulatus* and nine of *A. ? unispinus* were collected in the same band of shaly limestone.

Formation and locality.—Upper Cambrian: Weeks formation; (30n) about 3,750 feet (1,143 m.) above the Lower Cambrian in shales forming 1*c* of the Weeks formation,[1] and (30 o) about 3,950 feet (1,204 m.) above the Lower Cambrian in the shaly limestones forming 1*b* of the Weeks formation, both on the north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass; also (14v) shales of unknown stratigraphic horizon collected 1 mile (1.6 km.) south of Rainbow Valley, all in House Range,[2] Millard County, Utah.

ASAPHISCUS ? UNISPINUS, new species

Plate 61, fig. 1

This species resembles *Asaphiscus ? minor* in general appearance, but it has 10 thoracic segments instead of seven, and the eighth segment has a strong median spine on its axial lobe that extends back over the two posterior segments and the pygidium. From *A. ? granulatus* it differs in surface, number of thoracic segments, 10 instead of 11, and in having the thoracic spine on the eighth instead of the ninth segment.

Test dense and apparently minutely granulated.

There are nine specimens of this species in the collection, and all of them were associated in the shaly limestone with *A. ? minor* and at locality 30n with *A. ? granulatus*.

Formation and locality.—Upper Cambrian: Weeks formation; (30n) about 3,750 feet (1,143 m.) above the Lower Cambrian in shales forming 1*c* of the Weeks formation,[3] and (30 o) about 3,950 feet (1,204 m.) above the Lower Cambrian in the shaly limestones forming 1*b* of the Weeks formation, both on the north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass; also (14v) shales of unknown stratigraphic horizon collected 1 mile (1.6 km.) south of Rainbow Valley, all in House Range,[4] Millard County, Utah.

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[1] Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, p. 178.

[2] Idem, pl. 13.

[3] Idem, pl. 178.

[4] Idem, pl. 13.

ASAPHISCUS WHEELERI Meek

Plate 58, figs. 1, 1*a-g*

Bathyurellus (*Asaphiscus*) *wheeleri* Meek, 1873, Sixth Ann. Rept. U. S. Geol. Survey Terr., p. 485, footnote. (Brief description.)

Asaphiscus wheeleri White, 1875, Rept. U. S. Geog. and Geol. Expl. and Surv., West 100th Merid., Vol. 4, p. 43, pl. 2, figs. 1*a-f*. (Describes and illustrates species.)

Asaphiscus wheeleri Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, p. 220, pl. 31, figs. 3, 3*a*; pl. 25, fig. 9. (Describes and gives restored figure of species.)

Asaphiscus wheeleri Miller, 1889, North American Geol. and Pal., p. 530, text fig. 965. (Brief description and one figure.)

Asaphiscus wheeleri Grabau and Shimer, 1910, North American Index Fossils, Vol. 2, p. 289, fig. 1596. (Illustrates with reduced figure from Walcott.)

The description by White gives a very good conception of the dorsal shield of this species. Its most marked difference when compared with other species is the absence of genal spines. Specimens of the entire dorsal shield and the separate cephala and pygidia are very abundant in the Wheeler formation, east of Antelope Springs.

Formation and locality.—Middle Cambrian: (**3s, 3t, 8g, 4**) Wheeler formation; about 1,700 feet (518.2 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian in the shaly limestones and calcareous shales of the Wheeler formation, in the eastern part of Wheeler Amphitheater, east of Antelope Springs, House Range; and (**15b**) same horizon; near Swasey Spring, House Range, all in Millard County, Utah. .

Also (**10y, 10z**) Marjum formation; about 2,900 feet (884 m.) above the Lower Cambrian and 1,500 feet (457.2 m.) below the Upper Cambrian in the central part of the limestone forming 1*a* of the Marjum limestone about 1 mile (1.6 km.) south-southwest of Marjum Pass, House Range, Millard County, Utah.

ASAPHISCUS, species undetermined (1)

A number of pygidia that occur in a thin-bedded, dark-blue limestone in northern Wyoming have the general appearance of the pygidium of *Asaphiscus* (?) *capella*, and the associated free cheek has a genal spine and is more like that of *A*. (?) *capella*, but in the absence of a cranidium it is difficult to make even a tentative specific identification.

Formation and locality.—Middle Cambrian: (4d) Limestone; divide at head of Sheep Creek, north end of Teton Range, Wyoming.

ASAPHISCUS ?, species undetermined (2)

Plate 63, figs. 3, *3a*

This species is represented by a single pygidium that is doubtfully referred to *Asaphiscus*. Its appearance and characters are shown by the illustration.

Formation and locality.—Upper Cambrian: (119) Maryville limestone; beneath Nolichucky shale, on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County, Tennessee.

ASAPHISCUS, species undetermined (3)

This species is represented by a pygidium of the *Asaphiscus* (?) *capella* form and four crushed thoracic segments. It is noteworthy as being larger than other species referred to *Asaphiscus*. The pygidium has a length of 11 mm. and an anterior width of 19 mm.

Formation and locality.—Upper Cambrian: (30 o) Weeks formation; about 3,950 feet (1,204 m.) above the Lower Cambrian in the shaly limestones forming *1b* of the Weeks formation, on the north side of Weeks Canyon, about 4 miles (6.4 km.) south of Marjum Pass, House Range, Millard County, Utah.

DOUBTFUL SPECIES OF ASAPHISCUS

The following species from the Upper Cambrian or later formations are tentatively referred to *Asaphiscus* pending the discovery of better material that may lead to a more correct interpretation of their generic relations.

ASAPHISCUS ? AGATHO, new species

Plate 63, figs. 9, *9a*

This species is represented by a small *Asaphiscus*-like cranidium that is much like the cranidium of *Asaphiscus ? florus*. It differs in the width of the frontal limb and border and a narrower posterolateral limb. Length of cranidium, 5 mm. The associated pygidium is illustrated by figure *9a*.

Formation and locality.—Upper Cambrian ?: (107g) Kittatinny ? limestone; 100 feet more or less of limestone in middle of sandy dolomite 1,000 feet thick or more; 0.5 mile (0.8 km.) west of Drab, Blair County, Huntingdon quadrangle (U. S. G. S.), Pennsylvania.

Also from (123a) Maryville limestone; 4 miles (6.4 km.) northeast of Rogersville, Hawkins County, Tennessee.

ASAPHISCUS ? ANAXIS, new species

Plate 63, figs. 2, *2a*

This species is represented by a number of cranidia from 7 to 16 mm. in length. It is characterized by a narrow, upturned frontal border and rather broad, strong glabella and occipital ring.

Surface as far as known slightly roughened by what may be a fine granulation.

Cranidia of a similar type occur at several localities in the Maryville limestone.

Formation and locality.—Upper Cambrian: (107) Maryville limestone; Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.7 km.) northwest of Knoxville, Knox County; (119) beneath Nolichucky shale, on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County; also (123b) top of Maryville limestone, near base of Nolichucky shale; Rogersville, 0.5 mile (0.8 km.) east of depot on left of railway, in wagon road, and (125) north side of big creek below Harlan's mill, 4 miles (6.4 km.) northeast of Rogersville, last two in Hawkins County, all in Tennessee.

ASAPHISCUS ? DURIS, new species

Plate 63, figs. 8, *8a*

The cranidium representing this species is not unlike that of *A. ? florus,* figure 6, but is proportionally broader, and its outer surface is closely granulated.

Formation and locality.—Upper Cambrian ?: (107f); about 2 miles (3.2 km.) north of Bakers Summit, Bedford County, Pennsylvania.

ASAPHISCUS ? FLORUS, new species

Plate 63, figs. 6, *6a-b*

This is a small species, the cranidium of which would have been referred to *Ptychoparia* or *Liostracus* except that the associated pygidium has a slightly concave border and the anchylosed segments are clearly of the *Asaphiscus* type.

Formation and locality.—Upper Cambrian ?: (107g) Kittatinny ? limestone; Drab, Blair County, Pennsylvania.

A similar form occurs at locality 107e, Upper Cambrian ?: Kittatinny ?; limestone in lower part of upper quartzite division of the "Kittatinny"; 1 mile (1.6 km.) southwest of Ore Hill, and 4 miles (6.4 km.) south of Roaring Spring, in Bedford County, Hollidaysburg quadrangle (U. S. G. S.), Pennsylvania.

ASAPHISCUS ? cf. FLORUS, new species

Plate 63, fig. 7

This form is represented by a broken cranidium. It is closely related to *Asaphiscus ? florus,* except that the frontal limb is larger and the palpebral lobes a little longer in proportion to the length of the cranidium.

Formation and locality.—Upper Cambrian ?: (107e) Kittatinny ? limestone; 1 mile (1.6 km.) southwest of Ore Hill and 4 miles (6.4 km.) south of Roaring Spring, Bedford County, Pennsylvania.

BLAINIA, new subgenus

Blainia differs from *Asaphiscus* in the compact form of its convex dorsal shield and in its general appearance when compared directly with the dorsal shield of *Asaphiscus wheeleri,* the type of the genus. The pleural thoracic furrows are narrower than in the genotype, *A.* (*Blainia*) *gregarius;* the pygidium has a narrower outline and the pleural furrows extend down to the outer margin which gives quite a different aspect as compared with the broad, smooth border on the pygidium of *A. wheeleri.*

The species referred to *Blainia* have nine thoracic segments and six to 11 distinct anchylosed segments in the pygidium.

Genotype.—*Asaphiscus* (*Blainia*) *gregarius* Walcott.

As far as known, the subgenus is confined to one horizon of the Middle Cambrian Conasauga shales in Cherokee County, Alabama. *Asaphiscus* (*Blainia*) *gregarius* is a very abundant form on the siliceous nodules embedded in the shale and *A.* (*B.*) *paula* and *A.* (*B.*) *elongatus* are relatively rare.

ASAPHISCUS (BLAINIA) ELONGATUS, new species

Plate 63, figs. 4, 4*a*, 5, 5*a*

This is a large species represented by cranidia, and a pygidium that may or may not belong with the cranidium. The cranidium appears to be congeneric with that of the other species referred to *Asaphiscus* (*Blainia*), but it differs specifically in the elongate outline of the glabella, also of the pygidium, if the one referred to the species really belongs with it.

The form of the glabella and palpebral lobe is much like that of *A.* (*B.*) *paula,* but the frontal border curves backward at the center in front of the glabella. The associated pygidium is elongate and formed of about 12 anchylosed segments. From its size and form

it seems quite probable that it belongs with the cranidium to which it is referred.

Surface of both cranidium and pygidium finely granulated. The largest cranidium has a length of 21 mm. and associated pygidium of 19 mm. With the thorax of proportional length the dorsal shield would have a length of 60 mm., which would make it the largest species of the subgenus *Blainia.*

Formation and locality.—Middle Cambrian: (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in a dark argillaceous shale of the lower Conasauga formation; 3 miles (4.8 km.) east of Center, near Blaine, Coosa Valley, Cherokee County, Alabama.

ASAPHISCUS (BLAINIA) GLABRA, new species

Plate 63, figs. 1, 1*a-e*

This species is known only by the cranidium and associated pygidium and fragments of thoracic segments. The cranidium is much like that of *A.* (*B.*) *gregarius,* differing only in the relative widths of the frontal limb and border and slightly broader fixed cheeks. The associated pygidium differs in form, width of border, and length of axial lobe.

Exterior surface finely granulated. Judging from the separate parts, the dorsal shield probably equalled if not exceeded the size of the dorsal shield of *A.* (*B.*) *gregarius* and *A.* (*B.*) *paula.*

The fossils associated with *A.* (*B.*) *glabra* are *Hyolithes, Ptychoparia* sp., and a fine species of an undetermined *Olenoides.*

Formation and locality.—Middle Cambrian: (107x) Conasauga formation; compact oolitic limestone in boulder on hillside, Bull Run Knobs near creek, west of Copper Ridge, 2 miles (3.2 km.) south of Heiskell, Knox County, and 11 miles (17.7 km.) northwest of Knoxville, Tennessee.

ASAPHISCUS (BLAINIA) GREGARIUS, new species

Plate 62, figs. 1, 1*a-i*

This species is so well illustrated by the figures of plate 61 that a general description is unnecessary. The cephalon has rather large, free cheeks with medium size genal spines; the glabella is marked by three pairs of side furrows in the smaller specimens, as shown by figure 1*c,* but in the larger they are very slightly marked; the nine thoracic segments have narrow diagonal pleural furrows and a rather abrupt termination of the ends of the segments. The pygi-

dium has a narrow, convex axial lobe with seven to eight not very strongly defined rings that extend obliquely across the pleural lobes as flat segments separated by narrow, shallow furrows; the doublure is broad (fig. 1*f*) and finely striated.

Surface with fine, irregular granules set very close to each other and sometimes with a tendency to follow irregular lines that suggest that the granulation results from the breaking up of fine ridges.

The largest dorsal shield has a length of 43 mm.

Cephalon	13 mm.
Thorax	19 "
Pygidium	11 "
Width of thorax...........	20 "

Two enrolled specimens (see fig. 1*h*) show that the animal rolled up very much as in genera of the Asaphidæ, Proteidæ, etc.

This species is one of the most abundant of those occurring on the siliceous nodules of the Conasauga shales. It is associated with a large and varied fauna of a Middle Cambrian facies. One of the associated species, *A.* (*B.*) *paula,* is somewhat similar in form but differs in details of the cranidium and pygidium.

Formation and locality.—Middle Cambrian: (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in a dark argillaceous shale of the lower Conasauga formation; 3 miles (4.8 km.) east of Center, near Blaine, Coosa Valley, Cherokee County, Alabama.

Also (56y) fine, arenaceous, buff-colored shales; 1.75 miles (2.8 km.) southwest of Greenback, on the railroad just north of wagon-road crossing, Loudon County, Tennessee.

ASAPHISCUS (BLAINIA) PAULA, new species

Plate 62, figs. 2, 2*a-b*

This species has the same general characters of *A.* (*B.*) *gregarius,* such as form, nine segments in thorax, finely granulated surface, and size. It differs in outline of glabella and smaller palpebral lobes of cranidium, and the pygidium is quite dissimilar in details as may be seen by comparing figures 1*a,* 1*f,* 1*g* of plate 62 with figures 2, 2*a.* The same comparison may be extended to *A.* (*B.*) *glabra* (pl. 63, figs. 1, 1*a,* 1*b*).

The largest dorsal shield has a length of 45 mm.

Formation and locality.—Middle Cambrian: (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in a dark argillaceous shale of the lower Conasauga formation; 3

miles (4.8 km.) east of Center, near Blaine, Coosa Valley; and (**112**) argillaceous shale carrying fossiliferous cherty nodules of **90x**; 5 miles (8 km.) east-southeast of Center, both in Cherokee County, Alabama.

BLOUNTIA, new genus

General form of dorsal shield broadly elliptical, convex. Cephalon semicircular in outline with genal angles produced into short spines; border slightly rounded to convex; frontal limb of medium width and clearly defined. Glabella convex, slightly narrowing to a broadly round front, smooth or with slight traces of glabellar furrows; occipital ring flat or slightly rounded and separated from glabella by a narrow and often very indistinct furrow. Fixed cheeks narrow to medium width; postero-lateral limbs large, and anterior to the small palpebral lobes the cheeks curve slightly outward; a low, inconspicuous palpebral ridge crosses from the palpebral lobe to the slight dorsal groove beside the glabella. Palpebral lobe and eye small and situated about halfway of the length of the head, or in front of its transverse center. Free cheeks with border extended into a genal spine.

Thorax with convex axis and seven flat segments that curve abruptly downward at the geniculation, which gives a flattened appearance to the pleural lobes out to the geniculation; extremities of segments slightly falcate and with an enrollment facet on their anterior side; pleural furrow very shallow and best seen at the geniculation; it appears to start at the inner anterior margin of the segment and to extend diagonally across the segment to the posterior side of the narrowing space back of the enrollment facet.

Pygidium semioval in outline; axis convex, two-thirds or more of the length of the pygidium; axis and pleural lobes smooth or with indications of anchylosed segments; in the genotype the segments are indicated by a slight change of color along the lines of the furrows that usually outline the segments. The interior of the test shows seven or eight segments much more strongly outlined on the axis.

Surface dense and smooth as far as known.

Dimensions.—The only entire dorsal shield has a length of about 7 mm. Several cranidia indicate that some dorsal shields had a length of 10 mm. None of the species appear to have attained a much larger size.

Genotype.—*Blountia mimula* Walcott.

Stratigraphic range.—All of the species now referred to *Blountia* are from the Maryville limestone formation of the Middle Cambrian.

Geographic distribution.—All known species are from the eastern portion of the state of Tennessee.

Observations.—The genus *Blountia* includes a number of small trilobites that apparently came from the same line of descent as *Asaphiscus* and allied forms. It may be a degenerate from an *Asaphiscus*-like ancestor. The species *B. mimula* is represented by many cranidia and pygidia and one nearly entire dorsal shield.

A number of the species are represented by cranidia that might be referred to *Anomocarella* Walcott or *Liostracus* Angelin except that they have a general appearance that suggests a different genus. These include all of the following species except *B. anser* and *B. mimula*. *Blountia mimula* has but seven thoracic segments.

The species referred to the genus are:

Blountia ? alemon Walcott; Upper Cambrian (pl. 61, fig. 6).
Blountia alethes Walcott; Upper Cambrian (pl. 64, fig. 1).
Blountia alexas Walcott; Upper Cambrian (pl. 61, fig. 5).
Blountia amage Walcott; Upper Cambrian (pl. 64, fig. 3).
Blountia andreas Walcott: Upper Cambrian (pl. 64, fig. 2).
Blountia anser Walcott; Upper Cambrian (pl. 61, fig. 7).
Blountia mimula Walcott; Upper Cambrian (pl. 61, fig. 4).

BLOUNTIA ? ALEMON, new species

Plate 61, figs. 6, 6*a*

This is a small species distinguished by a broad glabella, small palpebral lobes, large postero-lateral limbs, and short frontal limbs from other species referred to the genus. The strong occipital furrow and narrow frontal limb suggest that it belongs to some other genus. The cranidium has a length of 4 mm.

Formation and locality.—Upper Cambrian: (119) Maryville limestone, beneath Nolichucky shale; on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County, Tennessee.

BLOUNTIA ALETHES, new species

Plate 64, figs. 1, 1*a-c*

This form differs from *Blountia mimula* in the form of its cranidium, glabella, palpebral lobes, and its associated pygidium. A large cranidium has a length of 8 mm., and an associated pygidium

doubtfully referred to the species has about the same length. The cranidium of *Blountia amage* is in the outline of its glabella and palpebral lobes nearer to *B. alethes* than any other species of the genus.

Formation and locality.—Upper Cambrian: (123b) Maryville limestone; Rogersville, 0.5 mile (0.8 km.) east of depot on left of railway in wagon road, Hawkins County, Tennessee.

BLOUNTIA ALEXAS, new species

Plate 61, figs. 5, 5*a*

This form is most nearly related to *Blountia anser;* it differs in the wider frontal border of the cranidium, shorter glabella, and smaller palpebral lobe. The glabella appears to be smooth.

Formation and locality.—Upper Cambrian: (125) Maryville limestone; north side of big creek below Harlan's mill, 4 miles (6.4 km.) northeast of Rogersville, Hawkins County, Tennessee.

BLOUNTIA AMAGE, new species

Plate 64, figs. 3, 3*a*

This form is characterized by its slightly conical, smooth glabella, gently rounded frontal limb and margin, and distinctly dorsal furrows. A cranidium has a length of 5 mm. An associated pygidium illustrated by figure 3*a* has a length of 6 mm.

The cranidium of *B. amage* is much like those of *B. alethes* and *B. andreas* (pl. 64, figs. 1, 2) except that they all differ in the details of the frontal limb and border from it and from each other.

The associated pygidium (fig. 3*a*) is somewhat similar to that associated with the cranidium of *B. alethes* (fig. 1*b*).

The cranidium has a length of 5.5 mm.

Formation and locality.—Upper Cambrian: (107) Conasauga formation (Maryville limestone); Bull Run Ridge, northwest of Copper Ridge, 11 miles (17.7 km.) northwest of Knoxville, Knox County, Tennessee.

BLOUNTIA ANDREAS, new species

Plate 64, fig. 2

This species is represented by a single specimen of the cranidium which is characterized by its broad frontal border and relatively short broad glabella which has a well-defined occipital furrow.

Formation and locality.—Upper Cambrian: (102a) Maryville limestone; summit of limestone, exposure at west end of limestone and shale knob, *first* right-hand road from Kingsport pike, 1.25 miles (2 km.) east of Rogersville, Hawkins County, Tennessee.

BLOUNTIA ANSER, new species

Plate 61, figs. 7, 7*a-b*

This very neat little species suggests in its cranidium *B. mimula,* but it differs in its frontal border and very narrow frontal limb. The associated pygidium is more like the pygidium associated with the cranidium of *B. alethes.*

One cranidium has a length of 3 mm. and a second 4 mm.

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, 2 to 3 miles (3.2 to 4.8 km.) south of New Market, Jefferson County, 18 miles (28.6 km.) east-northeast of Knoxville, Tennessee.

BLOUNTIA MIMULA, new species

Plate 61, figs. 4, 4*a-c*

One nearly entire dorsal shield of this species is taken as the genotype of the genus and is described in the generic description. It is the only specimen showing the seven segments of the thorax. *Blountia mimula* has thus far been found in limestones of the Appalachian region in Tennessee.

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, 2 to 3 miles (3.2 to 4.8 km.) south of New Market, Jefferson County, 18 miles (28.6 km.) east-northeast of Knoxville; (107c) west base of Copper Ridge; 11 miles (17.6 km.) northwest of Knoxville; (107a) Conasauga formation (Nolichucky shale zone); limestones and shales at the base of the Knox dolomite, west of the top of Copper Ridge, near the Southern Railway cut, about 10 miles (16.1 km.) northwest of Knoxville (Briceville folio); (119) Maryville limestone, beneath Nolichucky shale; on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County; (121a) 4 miles (6.4 km.) northeast of Rogersville, Hawkins County, on side of road leading from southeast of Harlans Knob to Amis postoffice; (123b) top of Maryville limestone, near base of Nolichucky shale; Rogersville, 0.5 mile (0.8 km.) east of depot on left of railway in wagon road, Hawkins County; and (125) north side of big creek below Harlan's Mill, 4 miles (6.4 km.) northeast of Rogersville, Hawkins County, all in Tennessee.

In addition to the above localities, pygidia have been tentatively referred to *B. minula* from two other localities:

(117b) Maryville limestone; Buckingham Ford road, 3.5 miles (5.6 km.) southeast of Greeneville, Greene County, Tennessee; and (139a) Conasauga formation; bluish limestones in shales on road near Wades Gap, near Chepultepec, Jefferson County, Alabama.

MARYVILLIA, new genus

The cranidium is not unlike that of *Blountia* except that the frontal limb and border merge into each other without a very definite line of demarcation between them. The smooth glabella, medium width of fixed cheeks and medium size palpebral lobes all are similar to the same parts of *Blountia,* but at the same time there is a suppressing of the relief of the glabella and fixed cheeks that gives a very distinctive character to the cranidium. The pygidia associated with the cranidia of both species, *M. arion* and *M. ariston,* are elongate with about 14 anchylosed segments as shown by the interior of the test of the axial lobe (pl. 64, figs. 4*a* and 5*a*). This type of pygidium suggests transition from *Blountia* to *Tsinania* as represented by such species as *T. canens* Walcott, *T. ceres* Walcott, *T. dictys* from the Upper Cambrian of eastern China.[1]

Surface of exterior of test with shallow pits and on some specimens it is apparently punctate.

Genotype.—Maryvillia arion Walcott.

MARYVILLIA ARION, new species

Plate 64, figs. 4, 4*a-c*

This species is represented by numerous specimens of the cranidium and pygidium from localities where both were associated in the same hand specimens of limestone. It is this association in different localities that leads to the conclusion that the cranidium and pygidium belong to one species.

The characters of the cranidium are well indicated by figures 4, 4′. The very narrow occipital ring with the almost flat glabella and the rapidly sloping, fixed cheeks are the most noticeable features.

The pygidium is found only as the interior of the test and the cast of it; the test clings in the matrix owing to its roughened outer surface which is more or less compactly covered by shallow pits or

[1] Research in China, Vol. 3, The Cambrian Faunas of China, 1913, pl. 23, figs. 3*b*, 3*c*, 4*a*, 5*a*, 6.

punctæ; the inner surface of the depressed axial lobe of the pygidium is marked by from 14 to 16 narrow rings that are extended rather faintly across the pleural lobes.

The largest cranidium has a length of 12 mm. and pygidium of 11 mm.

Maryvillia arion differs from *M. ariston* in the form of the frontal limb and border of the cranidium and the shape of the associated pygidium. Both species occur in the Maryville limestone but not at the same localities.

Formation and locality.—Upper Cambrian: (123b) Maryville limestone near its top beneath the Nolichucky shale; 0.5 mile (0.8 km.) east of depot on left of railway in wagon road, Rogersville, Hawkins County; (119) beneath Nolichucky shale, on Cub Creek, 1.5 miles (2.4 km.) southeast of Morristown, Hamblen County; and (107c) west base of Copper Ridge; 11 miles (17.7 km.) northwest of Knoxville, Knox County, all in Tennessee.

MARYVILLIA ARISTON, new species

Plate 64, figs. 5, 5*a*

Maryvillia ariston is known by its cranidium and a type of pygidium that is associated with it. It has the general characters of *M. arion*, but differs in the form of the combined frontal limb and border, and its associated pygidium is more elongate; the latter has 16 or more rings in its axial lobe and nearly smooth pleural lobes.

Surface of outer test finely pitted, apparently nearly punctate; inner surface of test finely granulated.

The largest cranidium has a length of 11 mm. and the pygidium 13 mm.

Formation and locality.—Upper Cambrian: (120) Maryville limestone; north of Bays Mountain, 2 to 3 miles (3.2 to 4.8 km.) south of New Market, Jefferson County, 18 miles (28.6 km.) east-northeast of Knoxville; and (126a) east side of Gap Creek section, 10 miles (16 km.) east of Knoxville, Knox County, both in Tennessee.

Family OLENIDÆ Burmeister

MARJUMIA, new genus

This genus appears to unite characters found in several genera. The cephalon is essentially that of *Asaphiscus*, the thorax that of *Ptychoparia*, and the pygidium that of several genera of the Olenidæ, such as *Peltura scarabæoides* Wahlenberg and *Parabolina megalops* Moberg.

The thorax has 14 segments, and the pygidium four and a terminal section on the axis. There are usually three pairs of border spines, but in one specimen there are four pairs (see pl. 65, fig. 4*a*). On the under side the base of the spines merges into the doublure (fig. 4*b*). The pygidium of *M. callas* has only one pair of border spines at its antero-lateral angle. These resemble closely the border spines of *Corynexochus* (*Bonnia*) *parvulus*. The variation in the number of border spines is not necessarily of generic value, and it may be in some instances of less than specific value.

Surface marked by fine, shallow pits.

The largest entire specimen of the dorsal shield of *Marjumia typa* has a length of 73 mm.

Genotype.—*Marjumia typa* Walcott.

The stratigraphic range is limited to the Marjum formation. *Marjumia typa* occurs about 250 feet (76 m.) and 575 feet (176 m.) below *M. callas*. As far as now known, species of the genus occur only in the House Range of western Utah.

MARJUMIA CALLAS, new species

Plate 65, figs. 3, 3*a-b*

This species is represented by specimens of the cranidium, free cheeks and pygidium. The cranidium and free cheeks are much like those parts in *Marjumia typa* except that the side furrows of the glabella are very faint in *M. callas*. The pygidium differs from that of *M. typa* in having but one marginal spine on each side and a shorter axis. The border spine appears to be a continuation of the anterior anchylosed segment that is merged into the border where it crosses and extends outward beyond it.

Surface of cranidium and pygidium marked by very fine shallow pittings. The largest cranidium has a length of 17 mm.

Formation and locality.—Middle Cambrian: (31r) Marjum formation; gray limestone forming lower portion of 1*a* of the section in cliff facing northeast, 1 mile (1.6 km.) southeast of Marjum Pass, House Range, Millard County, Utah.

MARJUMIA TYPA Walcott

Plate 65, figs. 4, 4*a-b*

Owenella typa WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 180 (Name listed under 1*c*, 1*d*. *Owenella* was preoccupied.)

The principal characters of this species are outlined in the remarks on the genus *Marjumia*. The species is quite abundant in dark-gray,

shaly limestones in association with a large Middle Cambrian fauna as follows at locality 11 q:

Micromitra sculptilis (Meek)
Micromitra (*Iphidella*) *pannula ophirensis* (Walcott)
Obolus mcconnelli pelias (Walcott)
Obolus rotundatus (Walcott)
Lingulella arguta (Walcott)
Acrothele subsidua (White)
Acrothele subsidua lævis Walcott
Acrotreta attenuata Meek
Acrotreta ophirensis Walcott
Eoorthis remnicha (N. H. Winchell)
Eoorthis thyone Walcott
Syntrophia ? unxia Walcott
Agnostus 3 spp.
Ptychoparia
Neolenus inflatus Walcott
Neolenus intermedius Walcott
Neolenus superbus Walcott
Orria elegans Walcott

Formation and locality.—Middle Cambrian: (11q, 30g) Marjum formation; about 2,300 feet (701 m.) above the Lower Cambrian, and 660 feet (203 m.) below the Upper Cambrian, in the limestone forming 1*c* of the Marjum formation, 2.5 miles (4 km.) east of Antelope Springs, in west face of ridge east of Wheeler Amphitheater, House Range; also (3x) same locality but slightly lower horizon, 1*d* of section; all in Millard County, Utah.

Genus LISANIA Walcott

Lisania WALCOTT, 1911, Smithsonian Misc. Coll., Vol. 57, p. 82. (Describes genus.)

Lisania WALCOTT, 1913, Research in China, Vol. 3, The Cambrian Faunas of China, p. 163. (Describes genus and illustrates genotype.)

Genotype.—*Anomocarella bura* Walcott.

Lisania has hitherto been identified only from China. The new species *L. ? breviloba,* from the Upper Cambrian of the Appalachian Province of North America and larger than any of the Chinese species, is doubtfully referred to the genus.

Lisania differs from *Pagodia* in having a longer eye lobe, narrower free cheeks, flatter frontal margin. *Pagodia* occurs with the Upper Cambrian fauna, *Lisania* with the Middle Cambrian fauna. From *Chuangia* it differs in its narrower frontal border, narrower fixed cheeks and quite unlike associated pygidium. The three genera, *Lisania, Pagodia,* and *Chuangia,* all have a strong, nearly smooth

glabella and a narrow frontal margin, and do not appear to come within the limits of *Agraulos, Anomocare, Ptychoparia, Coosia* or *Solenopleura*.

LISANIA ? BREVILOBA, new species

Plate 66, figs. 3, 3*a-c*

With only the cranidia of the type species for comparison it is difficult to identify this species as belonging to the genus, especially as the frontal border of *L. bura* has both a frontal limb and border of the *Anomocarella* type and *L. ? breviloba* has a flat or slightly concave frontal limb without a trace of a frontal border; in this character it is similar to the species *Lisania alala*,[1] from China. Not wishing to create a new genus to include *L. ? breviloba*, it is tentatively referred to *Lisania*.

The characters of the species are fairly well exhibited by the illustrations. The surface of the test is roughened by small shallow pits that on some specimens appear to go deep into its layers and give the surface a punctate appearance.

The largest cranidium has a length of 13 mm. A broken specimen (fig. 3) has nine segments of the thorax attached to a cranidium. A small cranidium (fig. 3*b*) indicates a rather large palpebral lobe, and ridge crossing the fixed cheek which is a character of species referred to *Lisania*. A pygidium (fig. 3*c*) was associated in the same rock with the cranidia and may be tentatively considered as possibly belonging to this species.

Formation and locality.—Upper Cambrian: (118a) Maryville limestone; Bird Bridge road, 1.5 miles (2.4 km.) south of Greeneville, Greene County, Tennessee.

Family ILLÆNIDÆ Corda

Genus ILLÆNURUS Hall

Illænurus HALL, 1863, Sixteenth Ann. Rept., New York State Cab. Nat. Hist., p. 176. (Describes genus and the genotype *Illænurus quadratus*.)

Illænurus HALL, 1867, Trans. Albany Inst., Vol. V, p. 167. (Reprint of paper of 1863.)

The genus *Illænurus* was proposed by Dr. James Hall for what he considered to be an *Illænus*-like trilobite of the "Primordial" fauna. The quadrate form of the cranidium and large free cheeks distin-

[1] Research in China, Vol. 3, The Cambrian Faunas of China, p. 165, pl. 15, figs. 19, 19′.

guishing it from *Illænus*. He did not compare it with *Symphysurus* Goldfuss, which has a somewhat quadrate cranidium as represented in its genotype *Asaphus palpebrosus* Dalman.[1]

Dr. W. C. Brögger described a new species of trilobite from a cephalon and pygidium, which he named *Symphysurus incipiens*,[2] that is evidently congeneric with *Symphysurus palpebrosus*. He also describes (p. 60) and illustrates (pl. III, figs. 9-11) another species, *S. augustatus* Sars and Boeck, that appears to be congeneric with Hall's genus *Illænurus*. This brings up the question of the distinction between *Symphysurus* and *Illænurus*.

The genotype of *Symphysurus, S. palpebrosus,* appears to be a form nearer to *Asaphus* than to *Illænus*. It has a distinctly marked cranidium with large eyes and a glabella expanded anteriorly. The thorax has eight segments and the pygidium has a distinct median lobe.

In contrast with *Symphysurus, Illænurus* more nearly resembles *Illænus*. The facial sutures in front of the eyes are subparallel to the longitudinal axis of the body; there are 10 segments of the *Illænus* type in the thorax and a transverse pygidium with only a slight indication of a central lobe. The eye of *Illænurus* is also smaller and less prominent, and the free cheek is proportionally larger.

Illænurus should be compared with *Psilocephalus* Salter,[3] although the latter differs in cranidium, thorax and pygidium from *Illænurus*.

Illænurus appears to be the progenitor in late Upper Cambrian time, and early post-Cambrian, of *Illænus,* a genus that obtained a great development in Ordovician and Silurian times.

In America there are no other species that appear to be congeneric with *Illænurus quadratus*.

Among species previously referred to *Illænurus* the following are now placed under other genera:

Illænurus canens Walcott, 1905 = *Tsinania* Walcott.
Illænurus ceres Walcott, 1905 = *Tsinania* Walcott.
Illænurus columbiana Weller, 1903 = *Platycolpus* Raymond, 1913.
Illænurus convexa Whitfield, 1878 = *Platycolpus* Raymond, 1913.
Illænurus ? dia Walcott, ? = ?
Illænurus dictys Walcott, 1905 = *Tsinania* Walcott.
Illænurus eurekensis Walcott, ? = *Platycolpus* Raymond, 1913.
Illænurus spp. *a* and *b* Walcott,[4] 1913 = *Asaphus?*

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[1] Ueber die Palæaden, Trilobiten, Nürnberg, 1828, p. 48, pl. 4, figs. *2a-c*.
[2] Sil. Etagen 2 und 3, Kristiania, 1882, p. 58, pl. 1, figs. 1, 2.
[3] Mem. Geol. Surv. Great Britain, Vol. 3, 1866, p. 315, pl. 6, figs. 9-12.
[4] Smithsonian Misc. Coll., Vol. 57, 1913, p. 336.

Illænurus sp. Walcott,[1] 1908 = *Tsinania* Walcott.
Illænurus sp. Walcott,[2] 1908 = Undt.
Illænurus sp. Walcott,[3] 1908 = *Asaphus ?*

ILLÆNURUS QUADRATUS Hall

Plate 45, figs. 1, 1*a-c*

Illænurus quadratus HALL, 1863, Sixteenth Ann. Rep., N. Y. State Cab. Nat. Hist., p. 176, pl. 7, figs. 52-57. (Description and illustration of species.)
Illænurus quadratus HALL, 1867, Trans. Albany Inst., Vol. 5, p. 168, pl. 2, figs. 52-57. (Reprint of paper of 1863.)
Illænurus quadratus CHAMBERLIN, 1883, Geol. Wisconsin, Vol. 1, p. 130, figs. 16 L-P. (Reproduces figures of Hall.)

To Hall's detailed description of the dismembered dorsal shield of this species I am now able to add that the thorax has 11 segments and that the pygidium is much smaller proportionally than the cephalon.

Formation and locality.—Upper Cambrian: (78) St. Lawrence formation; Osceola, Polk County, and (85) Prairie du Sac, Sauk County, Wisconsin.

(113) La Grange Mountain or Barn Bluff, near Red Wing, Goodhue County, Minnesota.

Family MESONACIDÆ Walcott. 1891

Genus MESONACIS Walcott, 1885

See *Mesonacis* WALCOTT, 1910, Smithsonian Misc. Coll., Vol. 53, p. 261.

MESONACIS GILBERTI (Meek)

Plate 45, fig. 3

Olenellus gilberti MEEK, 1874. For synonymy see Smithsonian Misc. Coll., Vol. 53, 1910, pp. 324, 325.

The discovery of a large, fine specimen of this species by Mr. Edward Sampson, of Philadelphia, affords the data upon which to change the generic reference of the species *gilberti* from *Olenellus* to *Mesonacis.* The specimen is almost a perfect dorsal shield 20 cm. in length. On the fifteenth thoracic segment a long median spine is attached that extends back over seven or eight small segments and a small plate-like pygidium.

This species appears to be represented by the same variations in both Nevada and British Columbia, Canada. These include variation

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 175, 1*a*.
[2] Idem, Vol. 53, 1908, p. 177, 2*a*.
[3] Idem, Vol. 53, 1908, p. 192, 1.

in width of border; width of frontal limb, and distance of eye from posterior margin.

A comparison with *Mesonacis vermontana* shows many points of resemblance between the Appalachian and Cordilleran species. The two are illustrated side by side on plate 45.

Formation and locality.—Lower Cambrian: (35n) Mount Whyte formation; eastern slope of Mount Odaray, below McArthur Pass, west-southwest of Lake O'Hara, British Columbia, Canada.

For other localities, see Smithsonian Misc. Coll., Vol. 53, 1910, pp. 329, 330.

Order PROPARIA Beecher

Family EODISCIDÆ Raymond

Eodiscidæ RAYMOND, 1913, Ottawa Nat., Vol. 27, p. 102.

The discovery of the eye and free cheeks of *Pagetia bootes* and *P. clytia*, with the facial sutures, cutting the margin posterior to the eye and in advance of the genal angles, places this section of the Eodiscidæ with the order Proparia and carries with it the closely related forms such as *Eodiscus punctatus, E. scanicus,* etc., that are not known to have had facial sutures and free cheeks.

For the species of the Eodiscidæ that have eyes and free cheeks and which otherwise are closely related to *Eodiscus punctatus* Salter, I propose the generic name *Pagetia*. This genus represents a stage of evolution of the free cheek and facial sutures corresponding to that of *Burlingia*,[1] but the large pygidium and cephalon indicate that it is an instance of reversion in the free cheeks and facial sutures to a primitive type, while the other parts of the dorsal shield indicate an advanced stage of development. If this conclusion is correct, these forms of the Eodiscidæ support the view of Professor Swinnerton[2] that the Proparian type is a reversion to a primitive type and not an evolution through the Opisthoparia to a more advanced type.

Genus **PAGETIA**, new genus

This genus is proposed for the forms of Eodiscidæ in which the eye, the free cheeks, and facial sutures are developed.

Genotype.—*Pagetia bootes* Walcott.

Stratigraphic range and geographic distribution.—The two known species occur in the Middle Cambrian, one (*P. bootes*) in the Burgess shale member of the Stephen formation, north of Field, British

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 14.

[2] Geol. Mag., Dec. 6, Vol. 2, 1915, p. 545.

Columbia, and the other (*P. clytia*) in the Middle Cambrian, Spence shale member of the Ute formation in southern Idaho.

PAGETIA BOOTES, new species

Plate 67, figs. 1, *1a-f*

I have been collecting material representing the Eodiscidæ[1] for many years, and hope within a few years to describe and illustrate the various forms that appear to belong in the family. At present two species that have eyes and facial sutures of the Proparia type appear to be of such interest as to warrant the publication of a preliminary notice of them.

Pagetia bootes has the same general form as *Eodiscus punctatus*, but it differs most radically in having true eye lobes and palpebral ridges across the fixed cheeks. The median caudal spine is also a marked character of *P. bootes*. The outer surface of the latter is slightly roughened by an obscure granulation that in places is so irregular that an obscure pitting is suggested.

The average length of the dorsal shield is from 5 to 7 mm.

As the illustrations exhibit the character of the dorsal shield, I will not describe the species in detail.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northwest of Burgess Pass, above Field, British Columbia, Canada.

PAGETIA CLYTIA, new species

Plate 67, figs. 2, *2a-e*

This species differs from *P. bootes* in its uniformly smaller size, greater proportional space between the glabella and frontal margin, more transverse cephalon and pygidium.

The dorsal shield averages from 2 to 3 mm. in length as compared with 5 to 7 mm. for *P. bootes*. Surface minutely granular.

Formation and locality.—Middle Cambrian: (55c) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

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[1] Raymond, Ottawa Naturalist, Vol. 27, 1913, p. 102.

NEW FORMATION NAME

CHISHOLM SHALES

Type locality.—Vicinity of Chisholm Mine and Half Moon Gulch, 2 to 3 miles northwest of Pioche, Lincoln County, Nevada.

Derivation.—From Chisholm Mine.

Character.—Pinkish-colored, compact, argillaceous shale with a few interbedded layers of limestone 3 to 15 inches in thickness.

Thickness.—About 100 feet in vicinity of Chisholm Mine and 125 feet in the Highland Range section.

Organic remains.—Middle Cambrian. At the Chisholm Mine (locality 31):

Eocystites ? longidactylus Walcott
Micromitra (*Iphidella*) *pannula* (White)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella dubia (Walcott)
Hyolithes billingsi Walcott
Zacanthoides typicalis Walcott
Ptychoparia piochensis Walcott
Anomocare ? parvum Walcott
Bathyuriscus howelli Walcott
Dolichometopus productus (Hall and Whitfield)

Observations.—The stratigraphic position of the Chisholm shale, as noted in the Highland Range section,[1] is about 1,200 feet (370 m.) above the Lower Cambrian with 3,000 feet of Cambrian limestones above it. In the upper portion of the latter limestone I found in 1887 the following (locality 88):

Owenella antiquata (Whitfield)
Sinuopea, 3 undt. spp.
Hyolithes attenuatus Walcott
Hyolithes ? corrugatus Walcott
Hyolithes curvatus Walcott
Dikelocephalus cf. *D. minnesotensis* Owen
Saukia pepinensis (Owen)
Eurekia dissimilis (Walcott)
Conaspis[2] sp. undt.
Arethusina ?? americana Walcott

This is the fauna listed on page 35, Bull. 30, U. S. Geol. Surv., 1886, and page 318, Bull. 81, U. S. Geol. Surv., 1891. The species

[1] Bull. U. S. Geol. Surv., No. 81, 1891, p. 318, Bed No. 21.
[2] New genus.

listed as *Illænurus* in 1886 and 1891 has not been found in the collection.

The stratigraphic position of the Chisholm shale corresponds in a general way to the Spence shale of the Ute formation of southern Idaho.[1]

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 7, 8, and 197.

DESCRIPTION OF PLATE 45

PAGE

Illaenurus quadratus Hall 406

FIGS. 1, 1*a*. ($\times$ 1.5.) Dorsal and side views of the cast of a dorsal shield preserved in fine-grained sandstone. U. S. National Museum, Catalogue No. 62614. (Locality **78.**)

1*b*. (Natural size.) Dorsal shield flattened in very fine-grained arenaceous shale. U. S. National Museum, Catalogue No. 62615.

From locality **85**, Upper Cambrian: Prairie du Sac, Wisconsin.

1*c*, 1*c'*. ($\times$ 1.5.) Dorsal and side views of a well-preserved cephalon from the same layer of sandstone as the specimen represented by fig. 1. U. S. National Museum, Catalogue No. 62616. (Locality **78.**)

1*d*, 1*d'*. ($\times$ 1.5.) Dorsal and side views of a cranidium, showing the form of the palpebral lobes and the course of the facial sutures. U. S. National Museum, Catalogue No. 62617.

From locality **78b**, Upper Cambrian: Saint Lawrence formation; Saint Croix River, near Osceola, Wisconsin.

1*e*. ($\times$ 1.5.) A pygidium associated with the specimens represented by figs. 1 and 1*c*. U. S. National Museum, Catalogue No. 62618.

The specimens represented by figs. 1, 1*c*, and 1*e* are from locality **78**, Upper Cambrian: Saint Lawrence formation; Saint Croix River, Osceola, Wisconsin.

Mesonacis vermontana (Hall) 407

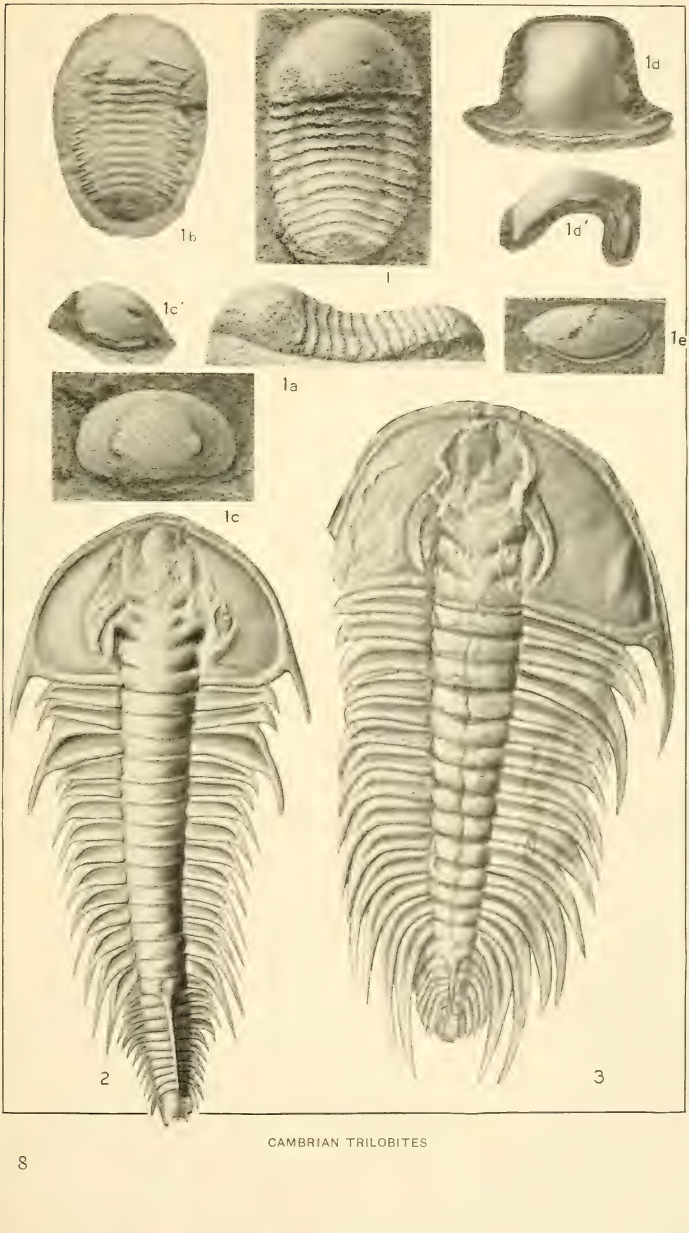
FIG. 2. (Natural size.) An entire dorsal shield from the type locality (**25**) at Georgia, Vermont, showing 14 thoracic segments of the *Olenellus* type, the spine-bearing segment, and ten segments of the *Mesonacis* type. U. S. National Museum, Catalogue No. 15399*a*.

From locality **25**, Lower Cambrian: Siliceous or finely arenaceous shale just above Parker's quarry, Georgia township, Franklin County, Vermont.

The specimen represented by fig. 2 has been figured by Walcott, Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 26, fig. 1.

Mesonacis gilberti (Meek) 406

FIG. 3. (About ½ natural size.) The illustration is taken from a plaster cast of the specimen now in the Geological Museum of Princeton University, Princeton, New Jersey, which was from locality **35n**, Lower Cambrian: Mount Whyte formation; eastern slope of Mount Odaray, above McArthur Pass, British Columbia, Canada. Plastotype. U. S. National Museum, Catalogue No. 62619.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 46

PAGE

Bathyuriscus (Poliella) powersi Walcott 351

FIG. 1. (× 2.) Type specimen of dorsal shield exclusive of free cheeks. Original specimen in collections Museum of Comparative Zoölogy, Cambridge, Massachusetts. Plastotype U. S. National Museum, Catalogue No. 62620.

The original specimen was collected from the Gallatin limestone, Pole Creek, Gallatin County, Montana.

Bathyuriscus haydeni (Meek) 341

FIG. 2. (× 1.5.) Photograph of the best specimen used by Meek in describing species. Note the large pygidium. U. S. National Museum, Catalogue No. 7863.

2a. (× 2.) Cast of a cranidium. U. S. National Museum, Catalogue No. 7863.

2b. (× 2.) Pygidium. U. S. National Museum, Catalogue No. 7863.

The specimens represented by figs. 2, *2a* and *2b* are weathered out on surface of dark, thin-bedded limestone at locality **302**, Middle Cambrian: Limestone east of West Gallatin River, above Gallatin City, Gallatin County, Montana.

Bathyuriscus (Poliella) occidentalis (Matthew).............................. 351

FIG. 3. (× 2.5.) Illustration from plaster cast made in matrix which is the type specimen of the species. Plastotype U. S. National Museum, Catalogue No. 62621. The specimen is from locality **14s**, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.

This figure is the same as that on plate 3, fig. 2, Canadian Alpine Journal, Vol. 1, No. 2, 1908.

Bathyuriscus ornatus Walcott 346

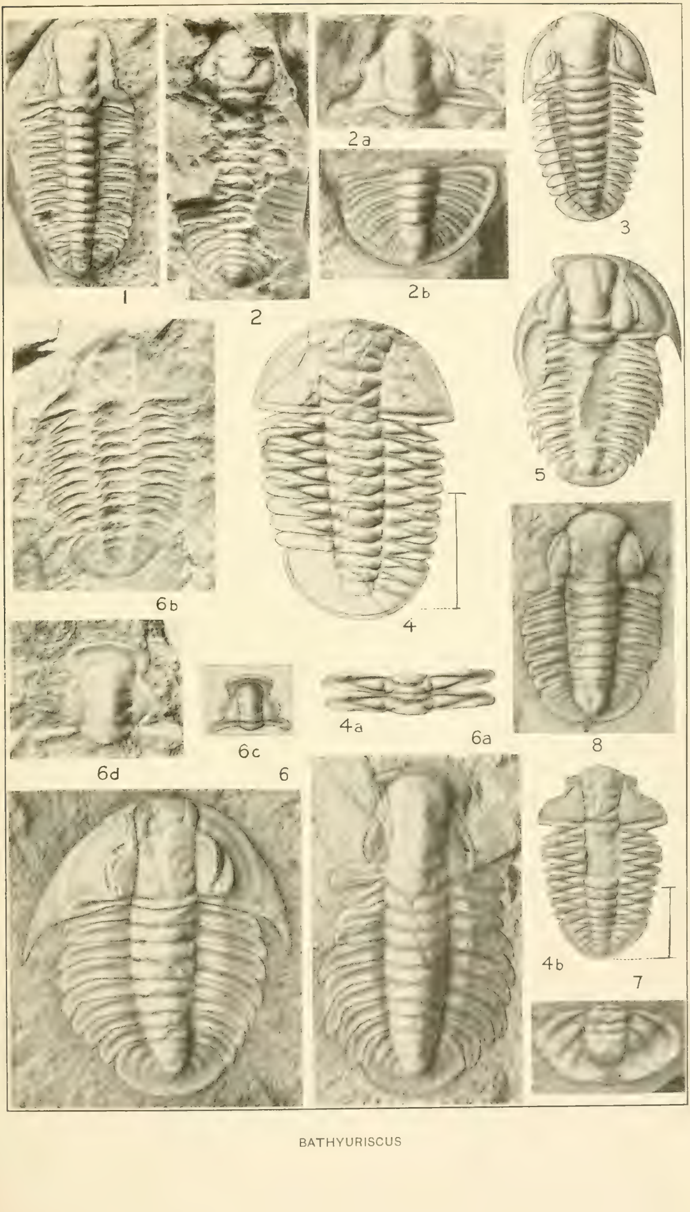
FIG. 4. (× 2.) A broken specimen, showing character of cephalon and thorax. U. S. National Museum, Catalogue No. 53420.

4a. (× 3.) Two segments of the thorax enlarged to show the details of the axial and pleural lobes. U. S. National Museum, Catalogue No. 53423.

4b. (× 2.25.) A small, nearly entire dorsal shield, with the exception of the free cheeks. U. S. National Museum, Catalogue No. 53421.

These figures are the same as those on plate 1, figs. 1, 3, 2, respectively, Smithsonian Miscellaneous Collections, Vol. 53, 1908; and 4 is also used on plate 3, fig. 3, Canadian Alpine Jour., Vol. 1, No. 2, 1908.

The specimens are from locality **14s**, Middle Cambrian: *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.



BATHYURISCUS

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Bathyuriscus (*Poliella*) *anteros* Walcott 349

FIG. 5. (× 2.25.) A crushed dorsal shield, the type specimen of the species. U. S. National Museum, Catalogue No. 62622.

From locality **55c**, Middle Cambrian: Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

Bathyuriscus (*Poliella*) *primus* (Walcott) 352

FIG. 6. (× 3.) An entire dorsal shield shortened by compression and slight distortion in the shale. U. S. National Museum, Catalogue No. 62623.

6a. (× 3.) Dorsal shield laterally compressed by slight distortion in the shale. U. S. National Museum, Catalogue No. 62624.

The specimens represented by figs. 6 and *6a* are from locality **35m**, Lower Cambrian: Mount Whyte formation (*Albertella* zone); 3 miles (4.8 km.) southwest of the head of Lake Louise, on east slope of Mount Whyte, Alberta, Canada.

6b. (× 2.) Matrix of a dorsal shield that is slightly distorted, and its cranidium has an unusually large and deep postero-lateral limb. U. S. National Museum, Catalogue No. 62625.

From locality **35e**, Lower Cambrian: Mount Whyte formation, Lakes Louise and Agnes Cambrian section; amphitheatre between Popes Peak and Mount Whyte, south of Lake Agnes, south of Laggan, on the Canadian Pacific Railway, in western Alberta, Canada.

6c (Natural size) and *6d* (× 2). Cranidium from an arenaceous shale. U. S. National Museum, Catalogue No. 62626.

From locality **58t**, Lower Cambrian: Sandy shale about 150 feet (45.7 m.) below the Middle Cambrian, just below the big cliff on the east shoulder of Castle Mountain, north of the Canadian Pacific Railway, Alberta, Canada.

Bathyuriscus (*Poliella*) sp. undt. (1) 355

FIG. 7. (Natural size.) Top view of pygidium. U. S. National Museum, Catalogue No. 62627.

From locality **35e**, Lower Cambrian: Mount Whyte formation, Lakes Louise and Agnes Cambrian section; amphitheatre between Popes Peak and Mount Whyte, south of Lake Agnes, south of Laggan, on the Canadian Pacific Railway, in western Alberta, Canada.

Bathyuriscus (*Poliella*) *caranus* Walcott 350

FIG. 8. (× 4.) An entire dorsal shield exclusive of the free cheeks. This is the type specimen of the species. U. S. National Museum, Catalogue No. 62628.

From locality **55c**, Middle Cambrian: Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles west-southwest of Liberty and 15 miles west of Montpelier, Bear Lake County, Idaho.

DESCRIPTION OF PLATE 47

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Bathyuriscus howelli Walcott 343

FIG. 1. (× 2.) Type specimen of the species. The pleural lobes are flattened a little in the shale. U. S. National Museum, Catalogue No. 15457.

1*a*. (× 2.) Cranidium partly crushed in the shale. U. S. National Museum, Catalogue No. 15457*a*.

1*b*. (× 2.) Pygidium partly crushed in the shale. U. S. National Museum, Catalogue No. 15457*b*.

The specimens represented by figs. 1, 1*a*-*b* are from the same layer of very fine arenaceous shale. 1 and 1*a* were illustrated on plate 30, figs. 2, 2*a*, in 1886 (Bull. U. S. Geol. Surv., No. 30).

From locality **31**, Middle Cambrian: Chisholm shales, at the Chisholm Mine, southwest slope of Ely Mountains, 3 miles (4.8 km.) northwest of Pioche, Lincoln County, Nevada.

Bathyuriscus rotundatus (Rominger) 346

FIG. 2. (× 1.5.) A dorsal shield that has been elongated by lateral compression in the shale. The free cheeks are restored in outline U. S. National Museum, Catalogue No. 62629.

This figure was used on plate 4, fig. 2, in 1908 (Canadian Alpine Jour., Vol. 1, No. 2).

2*a*. (× 1.5.) A very well-preserved dorsal shield. U. S. National Museum, Catalogue No. 62630.

2*b*. (Natural size.) A pencil and ink drawing of a small dorsal shield in which the slightly broken parts have been drawn as if unbroken.

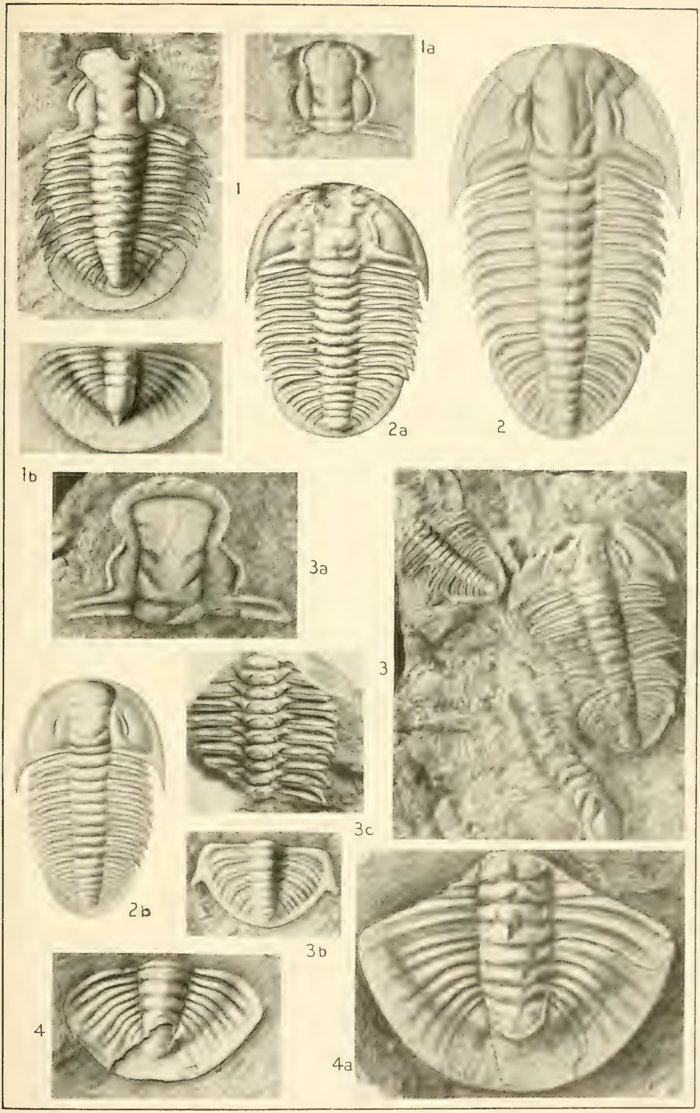
The specimens represented by figs. 2 and 2*a* are from locality **14s**, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 2,700 feet (823 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.

Bathyuriscus adæus Walcott 334

FIG. 3. (Natural size.) A broken dorsal shield restored in part. U. S. National Museum, Catalogue No. 62631.

3*a*. (× 2.) Cranidium. U. S. National Museum, Catalogue No. 62632.

3*b*. (× 1.5.) Pygidium that is of the same character as that of *Bathyuriscus rotundatus*. U. S. National Museum, Catalogue No. 62633.



BATHYURISCUS

Bathyuriscus adæus Walcott—Continued. PAGE

3*c*. (× 2.) Thoracic segments. U. S. National Museum, Catalogue No. 62634.

The specimens represented by figs. 3, 3*a-c* are from locality **58j**, Middle Cambrian: Stephen formation about 1,900 feet (579 m.) above the Lower Cambrian and 3,100 feet (945 m.) below the Upper Cambrian, near the base of the limestone forming 2 of the Stephen formation, on the east side of Mount Stephen about 3,000 feet (914 m.) above the Canadian Pacific Railway track (north of the tunnel), 3 miles (4.8 km.) east of Field, British Columbia, Canada.

Bathyuriscus ? bithus Walcott 340

FIG. 4. (Natural size.) Cranidium somewhat crushed in the argillaceous shale. U. S. National Museum, Catalogue No. 62635.

4*a*. (Natural size.) Fragment of a large pygidium. U. S. National Museum, Catalogue No. 62636.

The specimens represented by figs. 4 and 4*a* are from locality **55c**, Middle Cambrian: Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

DESCRIPTION OF PLATE 48

PAGE

Bathyuriscus anax Walcott 335

FIG. 1. (× 1.25.) Dorsal shield flattened in fine arenaceous shale. U. S. National Museum, Catalogue No. 62637.

1*a*. (Natural size.) Cranidium flattened in shale. U. S. National Museum, Catalogue No. 62638.

1*b*. (Natural size.) Cranidium compressed and elongated in the shale. U. S. National Museum, Catalogue No. 62641. (**30a.**)

1*c*. (× 2.) Pygidium flattened in shale. U. S. National Museum, Catalogue No. 62639.

1*d*. (× 3.) Hypostoma partly restored from an associated specimen. U. S. National Museum, Catalogue No. 62640.

The specimens represented by figs. 1, 1*a*, 1*c*, and 1*d* are from locality **55e**, Middle Cambrian: Spence shale horizon of the Ute formation; about 100 feet (30.5 m.) above the Brigham quartzite, at the mouth of the first small canyon south of Wasatch Canyon, east of Lakeview Ranch, Boxelder County, Utah.

The specimen represented by fig. 1*b* is from locality **30a**, Middle Cambrian: Shale on north side of Big Cottonwood Canyon, 1 mile (1.6 km.) below Argenta, in the Wasatch Mountains southeast of Salt Lake City, Salt Lake County, Utah.

Bathyuriscus atossa Walcott 336

FIG. 2. (× 1.5.) A very fine dorsal shield flattened in argillaceous shale. U. S. National Museum, Catalogue No. 62642.

2*a*. (× 2.) Cranidium. Note spine on occipital ring. U. S. National Museum, Catalogue No. 62643.

2*b*. (×3.) Cranidium. U. S. National Museum, Catalogue No. 62644.

The specimens represented by figs. 2, 2*a*-*b* are from locality **55c**, Middle Cambrian: Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about 6 miles (9.6 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

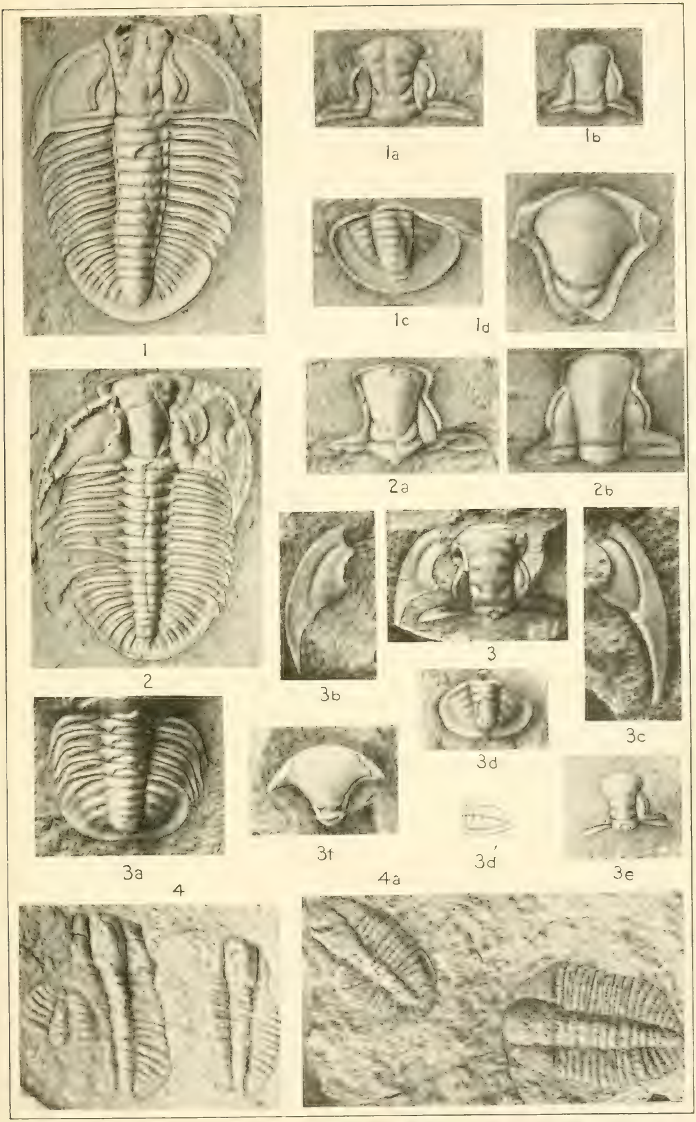
Bathyuriscus (*Poliella*) *sylla* Walcott 354

FIG. 3. (× 2.) Cranidium and free cheek. U. S. National Museum, Catalogue No. 62645.

3*a*. (× 2.) Four thoracic segments and pygidium. U. S. National Museum, Catalogue No. 62646.

3*b*. (× 1.5.) Free cheek. U. S. National Museum, Catalogue No. 62647.

3*c*. (× 2.) Free cheek. U. S. National Museum, Catalogue No. 62648.



BATHYURISCUS

Bathyuriscus (*Poliella*) *sylla* Walcott—Continued. PAGE

3*d*. (× 3.) Pygidium. U. S. National Museum, Catalogue No. 62649.

3*e*. (× 3.) A small cranidium showing glabellar furrows. U. S. National Museum, Catalogue No. 62650.

3*f*. (× 3.) Hypostoma with ears restored in outline. U. S. National Museum, Catalogue No. 62651.

The specimens represented by figs. 3, 3*a*-*f* are from locality **61 o,** Middle Cambrian: Chetang formation; gray shaly limestone in massive beds; on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

Bathyuriscus batis Walcott 337

FIG. 4. (Natural size.) Natural casts of distorted and compressed specimens in a fine quartzitic sandstone. U. S. National Museum, Catalogue No. 62652.

4*a*. (Natural size.) Dorsal shield, broadened by flattening in matrix. U. S. National Museum, Catalogue No. 62653.

The specimens represented by figs. 4 and 4*a* are from locality **59p,** Lower Cambrian: Millers Mountain, 10 miles (16 km.) north of Columbus and west of Belleville, Esmeralda County, Nevada.

DESCRIPTION OF PLATE 49

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Bathyuriscus (*Poliella*) *balus* Walcott 350

FIG. 1. (× 2.) Diagrammatic outline restored from distorted and compressed specimens.

1*a*. (Natural size.) Diagrammatic outline from a distorted dorsal shield preserving the median spine of the thorax. U. S. National Museum, Catalogue No. 62654.

1*b*. (× 2.) Cranidium. U. S. National Museum, Catalogue No. 62655.

1*c*. (× 2.) Broken cranidium and compressed thoracic segments. U. S. National Museum, Catalogue No. 62656.

1*d*. (× 2.) Crushed cranidium. U. S. National Museum, Catalogue No. 62657.

1*e*. (Natural size.) Laterally compressed dorsal shield. U. S. National Museum, Catalogue No. 62658.

1*f*. (× 2.) Dorsal shield longitudinally compressed. U. S. National Museum, Catalogue No. 62659.

1*g*. (× 2.) Dorsal shield obliquely compressed and distorted. U. S. National Museum, Catalogue No. 62660.

All the specimens represented by figs. 1. 1*a-g*, are casts in a fine argillaceo-arenaceous shale, at localities **48**, **48d**, Middle ? Cambrian: York ? formation; City of York, York County, Pennsylvania.

Bathyuriscus bantius Walcott 336

FIG. 2. (× 2.) Cranidium. U. S. National Museum, Catalogue No. 62661.

2*a*. (× 2.) Pygidium associated with specimen represented by fig. 2. U. S. National Museum, Catalogue No. 62662.

2*b*. (× 2.) Associated hypostoma. U. S. National Museum, Catalogue No. 62663.

2*c*. (Natural size.) A large associated pygidium. U. S. National Museum, Catalogue No. 62664. (**11**.)

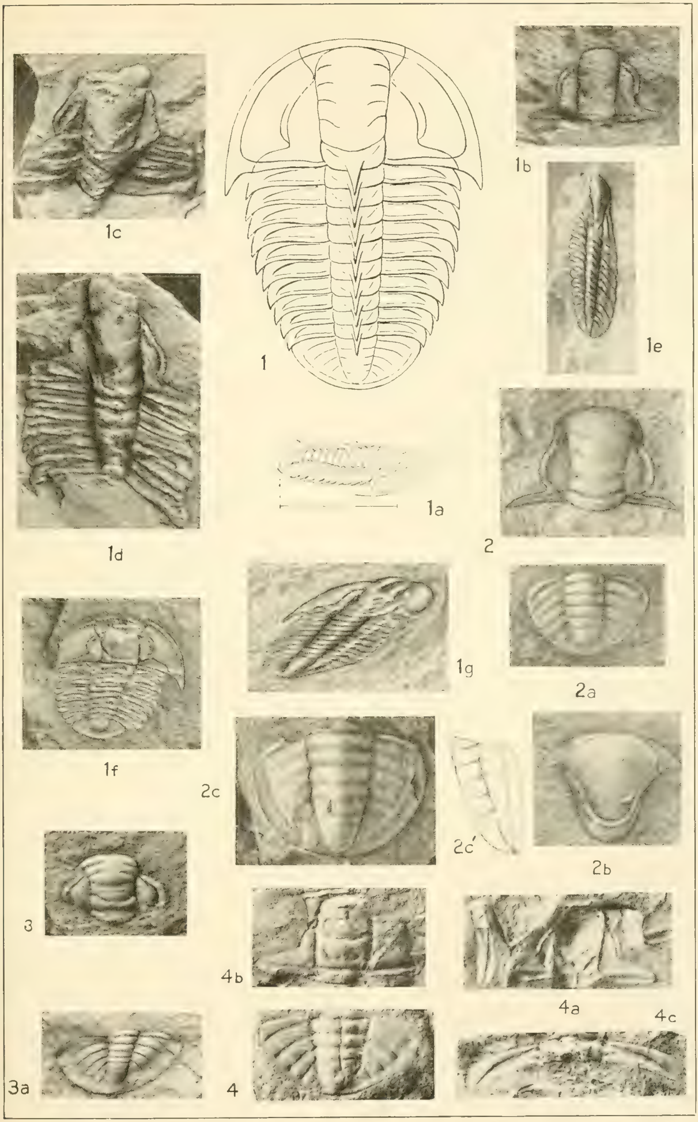
The specimens represented by figs. 2, 2*a-b*, are from a shaly sandstone of locality **12b**, Middle Cambrian: Rome formation; 12 miles (19.3 km.) northeast of Knoxville; and fig. 2*c*, from the same formation (locality **11**), 1 mile (1.6 km.) east of Post Oak Springs, Roane County, both in Tennessee.

Bathyuriscus sp. undt. (1) 348

FIG. 3. (× 2.) Cranidium. U. S. National Museum, Catalogue No. 62665.

3*a*. (Natural size.) Pygidium. U. S. National Museum, Catalogue No. 62666.

The specimens represented by figs. 3 and 3*a* are from locality **16e**, Middle Cambrian: Shales of Conasauga formation; railway cut 1 mile (1.6 km.) southwest of Piedmont, Calhoun County, Alabama.



BATHYURISCUS

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Bathyuriscus manchuriensis Walcott 344

FIG. 4. (× 3.) Pygidium. U. S. National Museum, Catalogue No. 58273.

4a, 4b. (× 3.) Cranidia flattened in argillaceous shale. These two cranidia are on a piece of shale recorded in U. S. National Museum Catalogue as No. 57587.

4c. (× 3.) Thoracic segment. U. S. National Museum, Catalogue No. 58272.

The specimens illustrated by figs. 4, *4a-ca* are from locality **36h,** Middle Cambrian: Fu-chóu series, argillaceous shales, Liau-tung, Manchuria, China.

The above figures are reproduced from plate 23, figs. *2, 2b,* and *2c* of Cambrian Faunas of China (Carnegie Inst. of Washington, Research in China, Vol. 3, 1913).

DESCRIPTION OF PLATE 50

FIG. 1. (Natural size.) Cranidium compressed in shale. U. S. National Museum, Catalogue No. 62667.

1*a*. (Natural size.) Associated free cheek. U. S. National Museum, Catalogue No. 62668.

1*b*. (× 4.) Small cranidium. U. S. National Museum, Catalogue No. 62669.

1*c*, 1*c'*. (× 2.) Dorsal view and profile of a small pygidium. U. S. National Museum, Catalogue No. 62670.

1*d*. (× 2.) A more elongate pygidium than that represented by fig. 1*c*. U. S. National Museum, Catalogue No. 62671.

1*e*, 1*e'*. (× 6.) A small associated pygidium (and side outline) that has well-defined furrows on the pleural lobes. U. S. National Museum, Catalogue No. 62672.

1*f*. (× 2.) Hypostoma. U. S. National Museum, Catalogue No. 62673.

1*g*. (× 2.) Posterior portion of an hypostoma. U. S. National Museum, Catalogue No. 62674.

1*h*, 1*i*. (× 2.) Portions of thoracic segments. U. S. National Museum, Catalogue Nos. 62675, 62676.

All of the specimens illustrated by figs. 1, 1*a-i*, are flattened in a fine Lower ? Cambrian argillaceo-arenaceous shale that occurs at locality **4v**, Gordon Creek, Powell County, Montana.

FIG. 2. (× 2.) Cranidium that has lost much of its convexity by being crushed in the shale. U. S. National Museum, Catalogue No. 62677.

2*a*. (× 2.) A cranidium preserving the postero-lateral limbs. U. S. National Museum, Catalogue No. 62678.

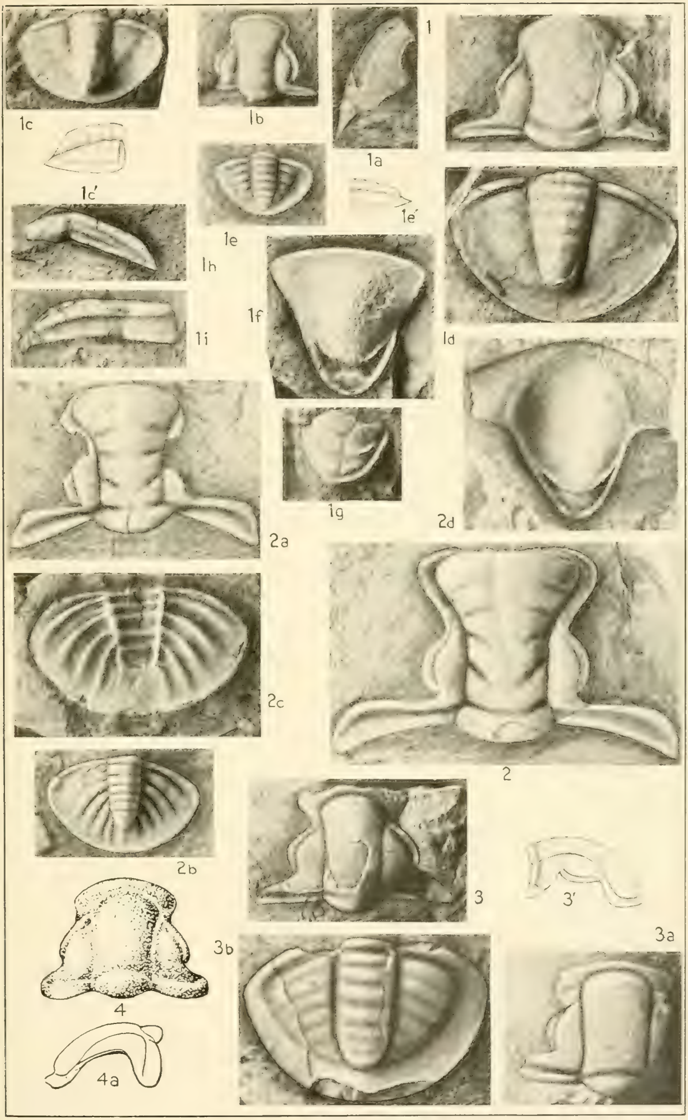
2*b*. (× 4.) A small associated pygidium. U. S. National Museum, Catalogue No. 62679.

2*c*. (Natural size.) Matrix of a large pygidium. U. S. National Museum, Catalogue No. 62680.

2*d*. (× 4.) Associated hypostoma on rock with specimen represented by fig. 2*b*. U. S. National Museum, Catalogue No. 62681.

The specimens represented by figs. 2, 2*a-d*, are more or less flattened in a fine arenaceo-argillaceous shale at locality **4w**, Lower ? Cambrian: Youngs Creek, Powell County, Montana.

FIGS. 3, 3'. (Natural size.) Dorsal and side views of a cranidium retaining a portion of the outer test. U. S. National Museum, Catalogue No. 62682.



CAMBRIAN TRILOBITES

Dolichometopus suecicus Angelin—Continued. PAGE

3a. (Natural size.) Dorsal view of a cranidium from which the outer surface has been exfoliated. U. S. National Museum, Catalogue No. 62683.

3b. (× 3.) Dorsal view of a pygidium associated with the cranidium of this species. U. S. National Museum, Catalogue No. 62684.

The specimens represented by figs. 3, 3′, *3a-b′*, are from locality **8w,** Middle Cambrian: Limestones of *Paradoxides forchhammeri* zone at Andrarum, Sweden.

4, *4a.* (Natural size.) Reproduction of figures by Matthew, which were drawn from Angelin's type specimen now in the Museum at Stockholm. (Trans. Roy. Soc. Canada. 2d ser., Vol. 3, 1897, Sec. 4, pl. 3, figs. *7a, 7b.*)

DESCRIPTION OF PLATE 51

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Dolichometopus tontoensis Walcott 373

FIG. 1. (Natural size.) A nearly complete dorsal shield, showing enlarged fifth segment. U. S. National Museum, Catalogue No. 62685.

1*a*. (Natural size.) A broken dorsal shield, with median nodes on thoracic segments. U. S. National Museum, Catalogue No. 62686.

The specimens represented by figs. 1 and 1*a* are from locality **74e**, Middle Cambrian: Bright Angel shales; Grand Canyon, Arizona.

1*b*. (Natural size.) Hypostoma and side profile. U. S. National Museum, Catalogue No. 62687.

1*c*. (Natural size.) Small convex cranidium. U. S. National Museum, Catalogue No. 62688.

1*d*. (Natural size.) Cranidium. U. S. National Museum, Catalogue No. 62689.

1*d′*. (× 2.) Free cheek. U. S. National Museum, Catalogue No. 62690.

1*d″*. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 62691.

1*e*. (Natural size.) Thoracic segment. Right half restored. U. S. National Museum, Catalogue No. 62692.

1*f*. (Natural size.) Large pygidium. U. S. National Museum, Catalogue No. 62693.

1*g*, 1*g′*. (Natural size.) Dorsal and side views of a pygidium. U. S. National Museum, Catalogue No. 62694.

1*h*. (Natural size.) Small pygidium. U. S. National Museum, Catalogue No. 62695.

The specimens represented by figs. 1*b-h* occur as casts in a hard gray sandstone and retain most of their natural convexity. They are from locality **74**, Middle Cambrian: Tapeats sandstone; Nunkoweap Valley, Grand Canyon, Arizona.

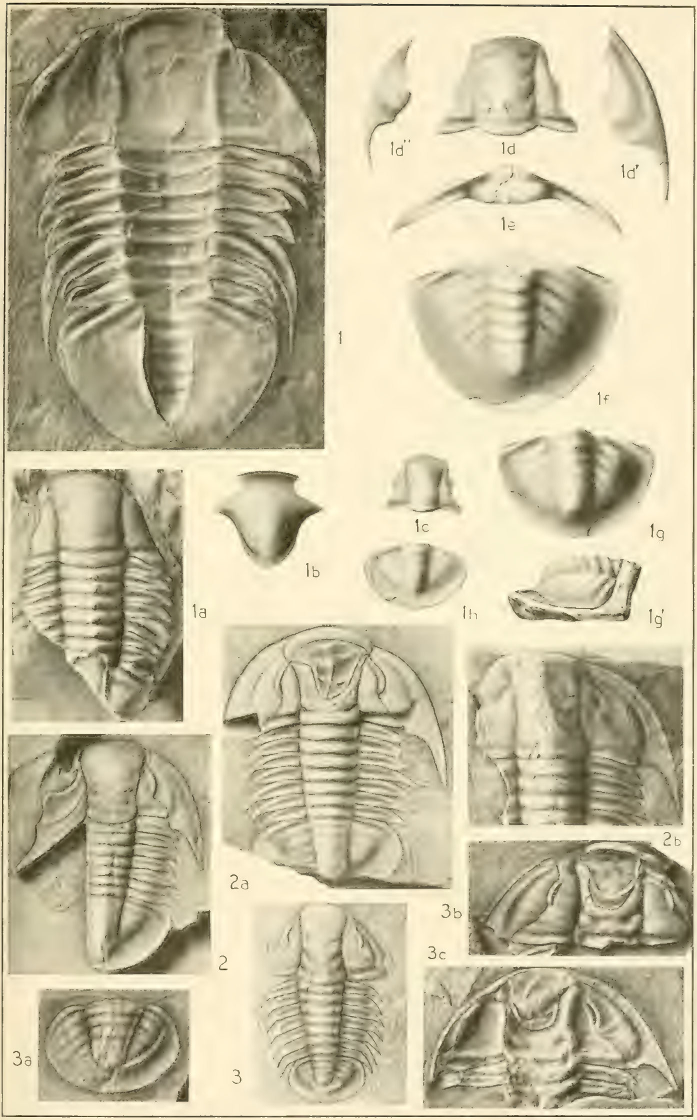
Dolichometopus baton Walcott 362

FIG. 2. (× 2.) Broken dorsal shield, partly restored. U. S. National Museum, Catalogue No. 62696.

2*a*. (× 3.) Imperfect dorsal shield with hypostoma showing beneath the glabella. U. S. National Museum, Catalogue No. 62697.

2*b*. (× 2.) Cranidium with free cheeks outlined. U. S. National Museum, Catalogue No. 62698.

The specimens represented by figs. 2, 2*a-b* are from a fine argillaceous shale at locality **3j**, Middle Cambrian: Wolsey ? shale; 6 miles (9.6 km.) west-northwest of Scapegoat Mountain, Powell County, Montana.



DOLICHOMETOPUS

Dolichometopus ? bessus Walcott 362

FIG. 3. (× 2.5.) Broken dorsal shield, showing characters of species. U. S. National Museum, Catalogue No. 62699.

3*a*. (× 2.) Pygidium. U. S. National Museum, Catalogue No. 62700.

3*b*. (× 2.) Cephalon and hypostoma in position. U. S. National Museum, Catalogue No. 62701.

3*c*. (× 2.) Matrix of the specimen represented by fig. 3*b*.

The specimens represented by figs. 3, 3*a-b* are flattened in a fine argillaceous shale from locality **62i**, Middle Cambrian: Sixteen Mile Canyon, Meagher County, Montana.

DESCRIPTION OF PLATE 52

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Dolichometopus boccar Walcott 363

FIG. 1. (Natural size.) Matrix of a dorsal shield, flattened in very fine arenaceous or siliceous shale. U. S. National Museum, Catalogue No. 62702.

From locality **14s**, Middle Cambrian: Stephen formation; Mount Stephen, British Columbia, Canada.

1*a*. (Natural size.) Partially restored figure of a dorsal shield. U. S. National Museum, Catalogue No. 62703.

1*b*. (Natural size.) Cranidium embedded in compact limestone. U. S. National Museum, Catalogue No. 62704.

1*c*. (Natural size.) Cranidium flattened in shaly limestone. U. S. National Museum, Catalogue No. 62705.

1*d*. (× 4.) Hypostoma. U. S. National Museum, Catalogue No. 62706.

1*e*. (Natural size.) Pygidium and five thoracic segments flattened in shaly limestone. U. S. National Museum, Catalogue No. 62707.

1*f*, 1*f'*. (× 2.) Dorsal and side views of a pygidium preserved in compact limestone. U. S. National Museum, Catalogue No. 62708.

The specimens represented by figs. 1*a-f* are from limestone at locality **57g**, Middle Cambrian: Stephen formation; Mount Bosworth, British Columbia, Canada.

Dolichometopus bion Walcott 363

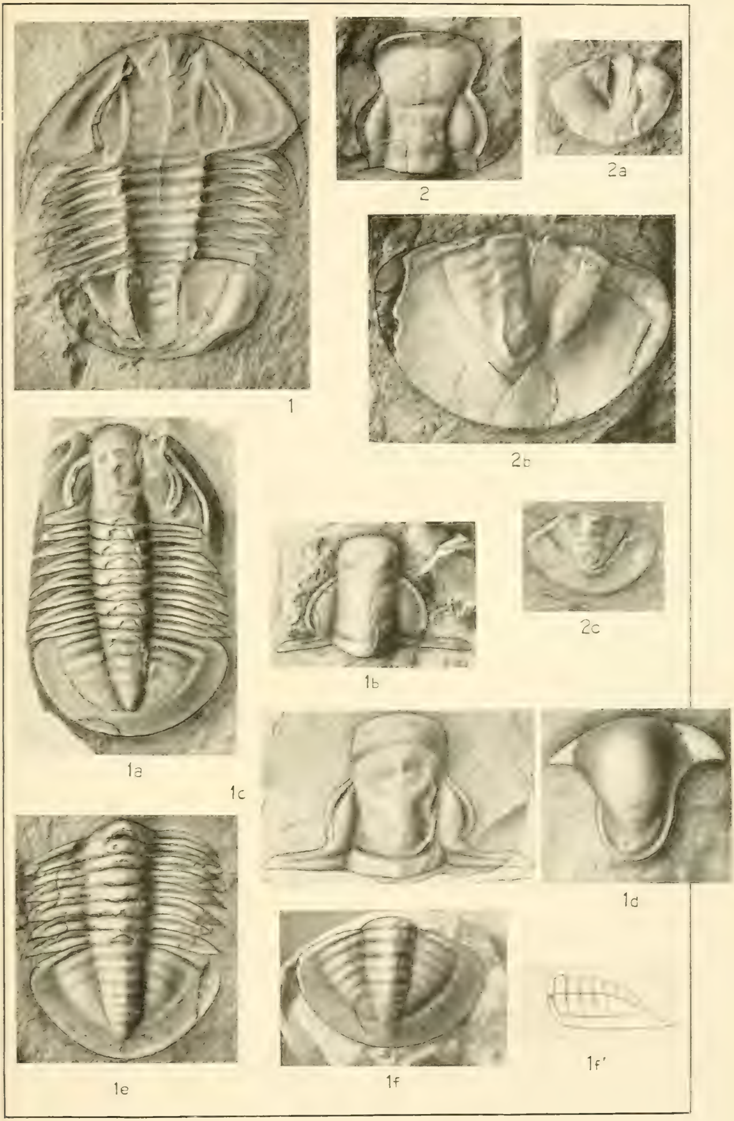
FIG. 2. (× 1.5.) Cranidium. U. S. National Museum, Catalogue No. 62709.

2*a*. (Natural size.) Matrix of a pygidium. U. S. National Museum, Catalogue No. 62710.

2*b*. (Natural size.) A large pygidium. U. S. National Museum, Catalogue No. 62711.

2*c*. (× 3.) A small pygidium enlarged. U. S. National Museum, Catalogue No. 62712.

The specimens represented by figs. 2, 2*a-c* occur in a fine argillaceous shale at locality **55c**, Middle Cambrian: Spence shale; 15 miles (24 km.) west of Montpelier, Idaho.



DOLICHOMETOPUS

DESCRIPTION OF PLATE 53

PAGE

Dolichometopus acadicus Matthew 360

FIG. 1. (× 2.) Cranidium.

1*a*. (× 2.) Outline of cranidium.

1*b*. (× 2.) Free cheek.

1*c*. (× 2.) Associated pygidium.

The above figures are reproduced from Matthew (Trans. Roy. Soc. Canada, 2d ser., Vol. 3, Sec. 4, 1897, pl. 3, figs. 6, 6*a-d*). The type specimens are in the collection of Dr. George F. Matthew, St. John, New Brunswick, Canada.

Locality, Hastings Cove, New Brunswick, Canada.

Dolichometopus productus (Hall and Whitfield) 369

FIG. 2. (Natural size.) Figure of a dorsal shield drawn from several specimens. The portion below the diagonal line is one piece. U. S. National Museum, Catalogue No. 15459.

This figure was published by me in 1886 (Bull. U. S. Geol. Surv., No. 30, pl. 30, fig. 1*i*).

2*a*. (Natural size.) Crushed and distorted cranidium. U. S. National Museum, Catalogue No. 15456*a*.

2*b*. (Natural size.) Crushed and distorted free cheek. U. S. National Museum, Catalogue No. 15456*b*.

2*c*. (Natural size.) Crushed and distorted pygidium and seven thoracic segments. U. S. National Museum, Catalogue No. 15456*c*.

2*d*. (Natural size.) Crushed and distorted pygidium. U. S. National Museum, Catalogue No. 15456*d*.

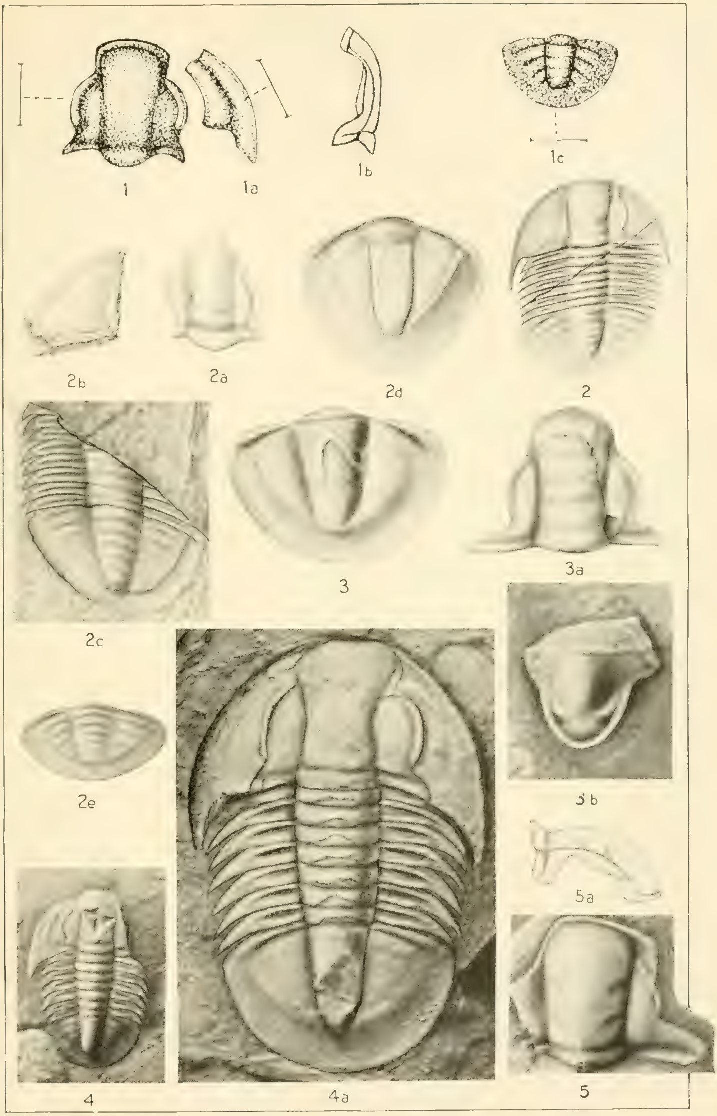
2*e*. (Natural size.) Crushed and distorted pygidium. U. S. National Museum, Catalogue No. 15456*e*.

The specimens represented by figs. 2*a-e* are the types illustrated by Hall and Whitfield on plate 2, figs. 31, 32, 33, 34, of the species *producta* and fig. 34 of the species *parabola* (Geol. Expl. 40th Par., Vol. 4, 1877).

The specimen represented by fig. 2 is from locality **3c,** Middle Cambrian: above Ophir City; and those by figs. 2*a-e* are from East Canyon, both in Oquirrh Range, Utah.

3. (Natural size.) Pygidium. U. S. National Museum, Catalogue No. 15455*a*.

3*a*. (Natural size.) Cranidium. U. S. National Museum, Catalogue No. 15455*b*.



DOLICHOMETOPUS

Dolichometopus productus (Hall and Whitfield)—Continued. PAGE

3*b*. (× 2.) Hypostoma. U. S. National Museum, Catalogue No. 15455*c*.

The specimens represented by figs. 3, 3*a-b* are from locality **31**, Middle Cambrian: Chisholm shale, Ely Mountains, Nevada. The two figures were first published in 1886 (Bull. U. S. Geol. Surv., No. 30, pl. 30, figs. 1*c*, 1*d*).

4. (× 3.) Small dorsal shield. U. S. National Museum, Catalogue No. 62713.

4*a*. (× 2.) Medium sized dorsal shield. By error the front of the glabella was shaded in so as to make it too wide. It has about the same outline as the glabella of figure 4. U. S. National Museum, Catalogue No. 62714.

The specimens represented by figs. 4, 4*a* occur in a fine arenaceous shale at locality **74e**, Middle Cambrian: Bright Angel shale; Grand Canyon, Arizona.

Dolichometopus ? expansus (Walcott) 368

FIGS. 5, 5*a*. (× 2.) Dorsal view and side outline of a cranidium which is the type and only specimen of the species. U. S. National Museum, Catalogue No. 15450.

The specimen was illustrated on plate 9, fig. 19, by Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884).

The specimen came from locality **55b**, Middle Cambrian: Eldorado limestone; Secret Canyon, Eureka District, Nevada.

DESCRIPTION OF PLATE 54

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Dolichometopus (?) *deois* Walcott 365

Fig. 1. (× 2.) Cranidium crushed down and flattened in shale. U. S. National Museum, Catalogue No. 58235.

1*a*. (× 2.) Free cheek associated with the specimen represented by fig. 1. U. S. National Museum, Catalogue No. 58237.

1*b*. (× 2.) Matrix of a pygidium associated in the same shale with the specimen represented by fig. 1. U. S. National Museum, Catalogue No. 58238.

1*c*. (× 2.) Pygidium with test removed, associated in shale with specimens represented by figs. 1, 1*a*, and 1*b*. U. S. National Museum, Catalogue No. 58239.

All of the specimens represented by figs. 1, 1*a-c*, are in argillaceous shale, from locality **35 o**, Middle Cambrian: Fu-chóu series, Liau-tung, Manchuria, China. [See Research in China, Pub. No. 54, Carnegie Inst. of Washington, Vol. 3, 1913, Walcott, Cambrian Faunas of China, pl. 21, figs. 13, 13*b*, 13*c* and 13*d*, respectively.]

1*d*. (× 1.5.) Cranidium referred to *Bathyuriscus asiaticus* Lorenz, by Lorenz. This occurs in shaly limestone. Plastotype U. S. National Museum, Catalogue No. 58539. Collected by Dr. Th. Lorenz at Wang-tschuang, Shan-tung, China. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 2*b*.]

1*e*, 1*e'*. (× 2.) Dorsal view and side outline of a cranidium. U. S. National Museum, Catalogue No. 58242. From locality **C 57**, Middle Cambrian: Kiu-lung group, south of Kao-kia-p'u, Shan-tung, China. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1*b*.]

1*f*, 1*f'*. (× 2.) Dorsal view and side outline of a cranidium. From locality **C 1**, Middle Cambrian: Kiu-lung group, 2 miles (3.2 km.) south of Yen-chuang, Shan-tung, China. U. S. National Museum, Catalogue No. 58240. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1.]

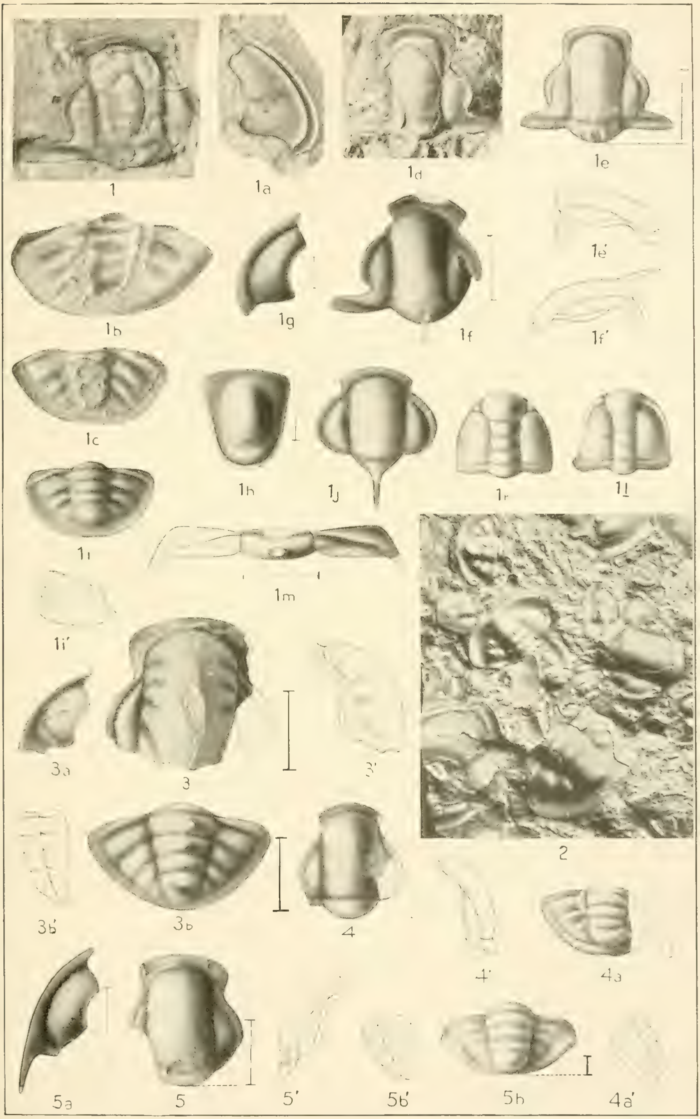
1*g*. (× 3.) Free cheek, associated with specimen represented by fig. 1*f*. U. S. National Museum, Catalogue No. 58241. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1*a*.]

1*h*. (× 3.) Hypostoma associated with specimen represented by fig. 1*e*. U. S. National Museum, Catalogue No. 58243. From locality **C 57**, Middle Cambrian: Kiu-lung group, south of Kao-kia-p'u, Shan-tung, China. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1c.]

1*i*, 1*i'*. (Natural size.) Dorsal view and side outline of a pygidium from locality **C 4**, in limestone, a little below the layer from which the specimen represented by fig. 1*f* was collected. U. S. National Museum, Catalogue No. 58248. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1*h*.]

1*j*. (× 10.) Cranidium of a young individual associated with specimen represented by fig. 1*e*. (**C 57**.) U. S. National Museum, Catalogue No. 58246. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1*f*.]

1*k*, 1*l*. (× 15.) Nepionic stages in the development of a trilobite, probably of this species. From locality **C 57**, Middle Cambrian: Kiu-lung group, south of Kao-kia-p'u, Shan-tung, China. U. S. National Museum, Catalogue Nos. 58244 and 58245. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 1*d* and 1*e*.]



DOLICHOMETOPUS

Dolichometopus (?) *deois* Walcott—Continued. PAGE

1*m*. (× 3.) Thoracic segment, associated with the specimen represented by fig. 1*e*. (**C57.**) U. S. National Museum, Catalogue No. 58247. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 1g.]

2. (× 1.5.) Photograph of one of the fragments of limestone collected by Dr. Th. Lorenz at Wang-tschuang, Shan-tung, China. The pygidia were referred to *Bathyuriscus asiaticus* Lorenz, by Lorenz, and the cranidia on the other side of the same piece of shaly limestone to the same species. (See fig. 1*d* above.) Plastotype. U. S. National Museum, Catalogue No. 58538. [See Lorenz, Zeits. deuts. geol. Gesells., Vol. 58, 1906, pl. 5, figs. 1-5. Also Walcott, Cambrian Faunas of China, pl. 22, fig. 2.]

Dolichometopus (?) *alceste* Walcott 361

FIGS. 3, 3′. (× 2.) Type specimen showing parts of cranidium in front of occipital furrow; with side outline of same. From locality **C 4**, Middle Cambrian: Kiu-lung group, south of Yen-chuang, Shan-tung, China. U. S. National Museum, Catalogue No. 58249. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 3, 3′.]

3*a*. (Natural size.) Free cheek associated with this species at locality **C 4**. U. S. National Museum, Catalogue No. 58250. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 3*a*.]

3*b*, 3*b*′. (× 1.5.) Pygidium associated with this species a little lower in the section (**C 1**). U. S. National Museum, Catalogue No. 58251. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 3*b*, 3*b*′.]

Dolichometopus (?) *derceto* Walcott 367

FIGS. 4, 4′. (× 3.) Type specimen showing portions of the cranidium; and side outline of same. From locality **C 1**, Middle Cambrian: Kiu-lung group, south of Yen-chuang, Shan-tung, China. U. S. National Museum, Catalogue No. 58252. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 4, 4′.]

4*a*, 4*a*′. (× 3.) Fragment of a pygidium (and side outline) from locality **C 2**, just above the locality of specimen represented by fig. 4. U. S. National Museum, Catalogue No. 58253. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 4*a*, 4*a*′.]

Dolichometopus (?) *dirce* Walcott 368

FIGS. 5, 5′. (× 2.) Type specimen, showing central parts of cranidium; and side outline of same. From locality **C 24**, Middle Cambrian: Ch'ang-hia formation, east of Ch'ang-hia, Shan-tung, China. U. S. National Museum, Catalogue No. 58254. [See Walcott, Cambrian Faunas of China, pl. 22, figs. 5, 5′.]

5*a*. (Natural size.) Large free cheek associated with specimen represented by fig. 5. U. S. National Museum, Catalogue No. 58255. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 5*a*.]

5*b*, 5*b*′. (× 4.) Small pygidium associated with specimen represented by fig. 5. U. S. National Museum, Catalogue No. 58256. [See Walcott, Cambrian Faunas of China, pl. 22, fig. 5*b*.]

DESCRIPTION OF PLATE 55

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Corynexochus spinulosus Angelin 323

Fig. 1. (× 4.) Cranidium.

1*a*. (× 4.) Side view of cranidium represented by fig. 1.

1*b*. (× 4.) A small pygidium associated with cranidia of this species.

The above figures are from Grönwall, plate 4, figs. 3*a*, 3*b*, who illustrated the type specimens of Angelin, which are now in the Museum at Stockholm. They come from the *Paradoxides forchhammeri* zone, Andrarum limestone at Andrarum, Sweden.

Corynexochus bornholmiensis Grönwall 313

Figs. 2, 2*a*. (× 4.) Dorsal and side views of the typical cranidium.

2*b*. (× 4.). Pygidium associated with the cranidium represented by figs. 2, 2*a*.

The above figures are from Grönwall, plate 4, figs. 1*a*, 1*b*, 2. The type specimens are in the Mineralogical Museum [at Stockholm?]. They came from the *Agnostus nathorsti* zone of the Middle Cambrian limestone of Bornholm Island.

Corynexochus delagei Miquel 317

Fig. 3. (× 4.) Cranidium laterally compressed and distorted. U. S. National Museum, Catalogue No. 62715.

3*a*. (× 4.) Pygidium compressed and distorted. U. S. National Museum, Catalogue No. 62716.

The specimens represented by figs. 3, 3*a* are from locality **152d,** Middle Cambrian: calcareous shale of Coulouma, Hérault, France.

Corynexochus clavatus (Walcott) 316

Figs. 4, 4′. (× 6.) Dorsal and side views of the type specimen of cranidium. U. S. National Museum, Catalogue No. 17454*a*.

4*a*. (× 12.) Diagrammatic figure based on several specimens of the cranidium. This figure is the same as that published in 1887, American Jour. Sci., Vol. 34, plate 1, fig. 3; idem, 1891, Tenth Ann. Rept., U. S. Geol. Surv., plate 98, fig. 4.

4*b*. (× 6.) A minute cranidium. U. S. National Museum, Catalogue No. 17454*b*.

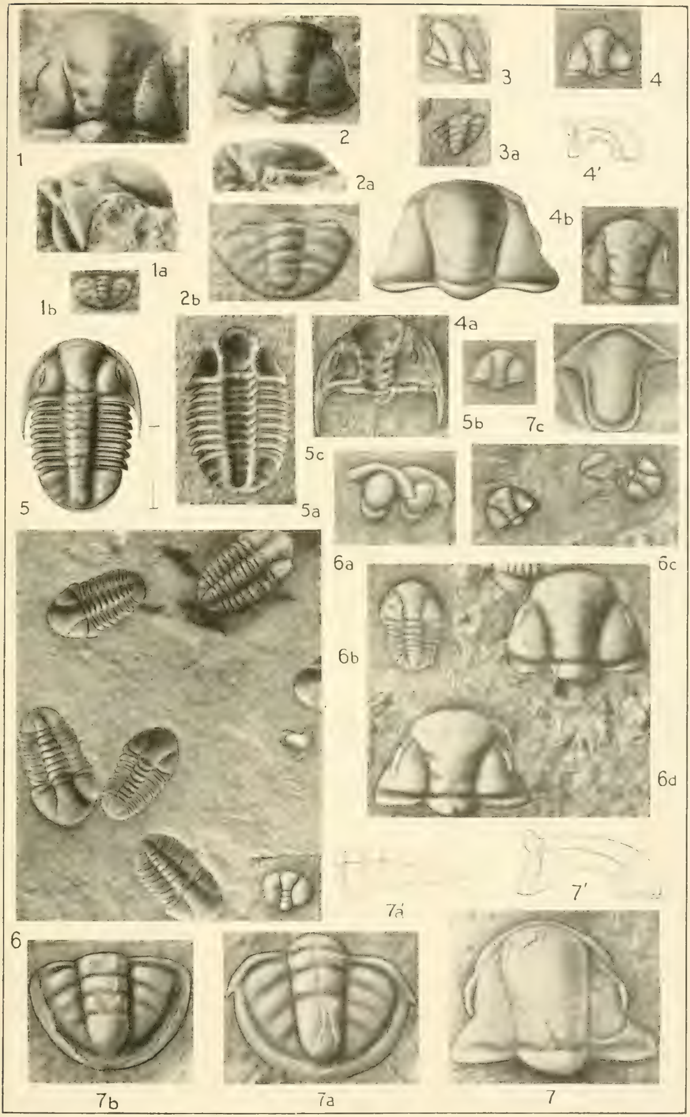
The specimens represented by figs. 4, 4*b* are from the Lower Cambrian limestone of localities **38a** and **43a,** Washington County, New York.

Corynexochus stephenensis (Walcott) 324

Figs. 5, 5*a*. (× 2.) Nearly entire dorsal shield with the free cheeks restored from other specimens and matrix of same. U. S. National Museum, Catalogue No. 61731.

From locality **14s,** Middle Cambrian: Stephen formation; Mount Stephen, British Columbia, Canada.

This is the same figure as that of pl. 3, fig. 4 (Canadian Alpine Jour., Vol. 1, 1908) and fig. 8, pl. 36 (Smithsonian Misc. Coll., Vol. 64, 1915). It is reproduced here in order that direct comparison may be made with other species of *Corynexochus.*



CORYNEXOCHUS

Corynexochus stephenensis (Walcott)—Continued. PAGE

5*b*. (× 8.) A minute cranidium tentatively referred to this species. U. S. National Museum, Catalogue No. 62717.

From locality **35k**, Middle Cambrian: Burgess shale; 1 mile (1.6 km.) northeast of Burgess Pass, British Columbia, Canada.

5*c*. (× 2.) Matrix of cranidium. U. S. National Museum, Catalogue No. 62718.

From locality **14s**, Middle Cambrian: Stephen formation; Mount Stephen, British Columbia, Canada.

Corynexochus minor (Walcott) 319

FIG. 6. (× 6.) Group of specimens on a fragment of shale. U. S. National Museum, Catalogue No. 26703.

6*a*. (× 8.) Form of hypostoma abundantly associated with this species. U. S. National Museum, Catalogue No. 62719.

6*b*. (× 8.) Small dorsal shield with three thoracic segments. U. S. National Museum, Catalogue No. 61730.

The specimens represented by figs. 6, 6*b* were illustrated by figs. 7, 7*b*, plate 36, Smithsonian Misc. Coll., Vol. 64, 1915.

6*c*, 6*d*. (× 8.) Cranidia illustrating variation in form from small specimens 0.5 mm. in length to adult size. U. S. National Museum, Catalogue Nos. 6*c*, 62720, and 6*d*, 62721.

The specimens represented by figs. 6, 6*a-d* are from locality **1**, Middle Cambrian: Manuels River, above Conception Bay, near Topsail Head, Newfoundland.

Corynexochus senectus (Billings) (see pl. 56, figs. 1, 1*a-g*) 319

FIGS. 7, 7′. (× 3.) Dorsal and side views of a partially exfoliated cranidium, with slight indication of lateral glabellar furrows. U. S. National Museum, Catalogue No. 62722.

7*a*, 7*a*′. (× 3.) An associated pygidium that has been slightly elongated. U. S. National Museum, Catalogue No. 62723.

7*b*. (× 3.) Associated pygidium, partly flattened by compression. U. S. National Museum, Catalogue No. 62724.

7*c*. (× 4.) Associated hypostoma. U. S. National Museum, Catalogue No. 62725.

The specimens represented by figs. 7*a-b* are from locality **61d**, Lower Cambrian: Mount Whyte formation; southwest slope of Mount Shaffer, British Columbia, Canada.

DESCRIPTION OF PLATE 56

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Corynexochus senectus (Billings) (see pl. 55, figs. 7, *7a-c*) 319

FIGS. 1, 1′. (× 3.) Dorsal view and side outline of cranidium with most of test exfoliated. U. S. National Museum, Catalogue No. 62726.

1a, *1b*. (× 5.) Small cranidia somewhat distorted. U. S. National Museum, Catalogue Nos. 62727, 62728.

1c, *1c′*. (× 4.) Cranidia shortened by slight distortion, with side outline of the longest one. U. S. National Museum, Catalogue No. 62729.

1d. (× 6.) Associated hypostoma. U. S. National Museum, Catalogue No. 62730.

1e, *1e′*. (× 4.) Dorsal and side view of a pygidium. U. S. National Museum, Catalogue No. 62731.

1f. (× 4.) Fragment of a pygidium showing an antero-lateral spine and a trace of a second spine back of it. U. S. National Museum, Catalogue No. 62732.

1g. (× 4.) Small pygidium. U. S. National Museum, Catalogue No. 62733.

The specimens represented by figs. 1, *1a-g*, are from limestone at locality **41 l**, Lower Cambrian: Bonne Bay, Newfoundland.

Corynexochus bubaris Walcott 314

FIGS. 2, 2′. (× 3.) Dorsal and side view of a laterally compressed cranidium. U. S. National Museum, Catalogue No. 62734.

2a. (× 3.) Side view of a convex cranidium. U. S. National Museum, Catalogue No. 62735.

2b. (× 8.) Ridged surface of a glabella. U. S. National Museum, Catalogue No. 62736.

The specimens represented by figs. 2, *2a-b* are from limestone at locality **20**, Lower Cambrian: Bic Harbor, Quebec, Canada.

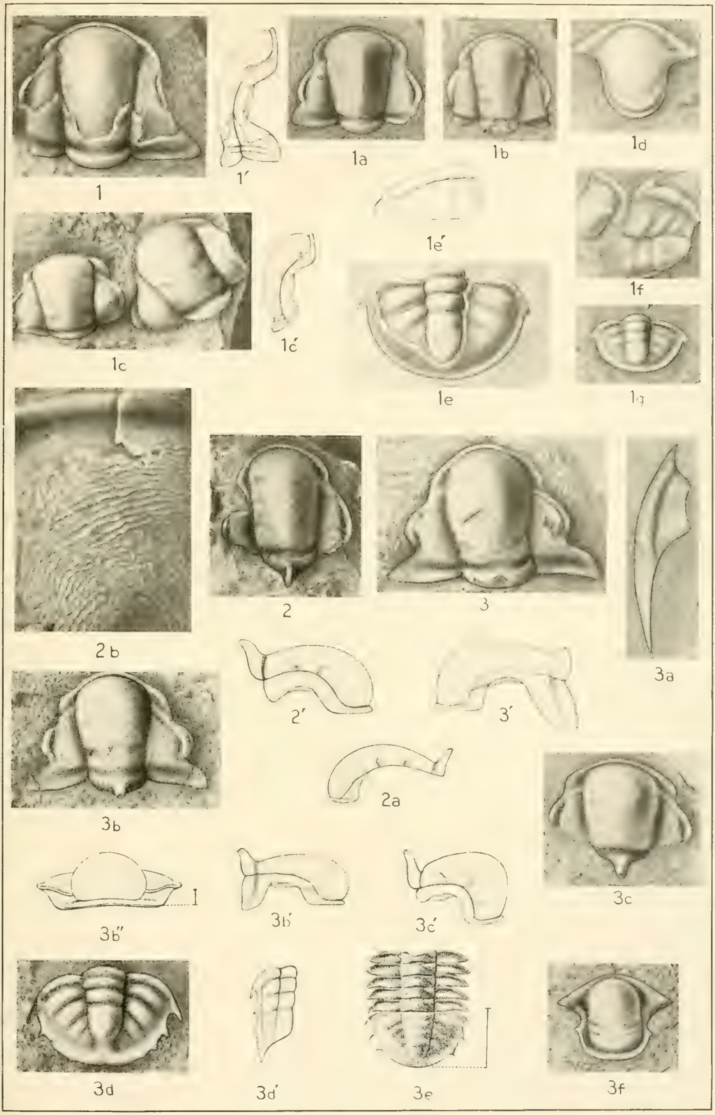
3, 3′. (× 2.) Dorsal and side view of a large cranidium. U. S. National Museum, Catalogue No. 62737.

3a. (× 3.) Free cheek with outline of spine restored from another specimen. U. S. National Museum, Catalogue No. 62738.

3b, *3b′*, *3b″*. (× 3.) Dorsal, side and front views of a very perfect and convex cranidium. U. S. National Museum, Catalogue No. 62739.

3c, *3c′*. (× 3.) Dorsal and side view of a cranidium shortened by distortion. U. S. National Museum, Catalogue No. 62740.

3d, *3d′*. (× 2.) Dorsal and side view of a large pygidium. U. S. National Museum, Catalogue No. 62741.



CORYNEXOCHUS

Corynexochus bubaris Walcott—Continued. PAGE

3e. (× 2.) Pen and ink sketch of five thoracic segments and pygidium. The original specimen has crumbled on the surface so that it cannot be photographed. U. S. National Museum, Catalogue No. 62742.

3f. (× 4.) Hypostoma. U. S. National Museum, Catalogue No. 62743.

The specimens represented by figs. 3, *3a-g* are from a leached calcareous sandstone at locality **49**, Lower Cambrian: near Emigsville, York County, Pennsylvania.

DESCRIPTION OF PLATE 57

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Corynexochus (*Bonnia*) *parvulus* (Billings) (see pl. 64, fig. 6) 328

FIG. 1. (× 10.) Enlargement of cranidium shown by 1*b*, to illustrate surface.

1*b*, 1*b*′. (× 3.) Dorsal and side views of a finely preserved cranidium. U. S. National Museum, Catalogue No. 62744.

1*c*, 1*c*′. (× 3.) Dorsal and side views of a pygidium. U. S. National Museum, Catalogue No. 62745.

The specimens represented by figs. 1, 1*b-c* are from the limestone of locality **41k**, Lower Cambrian: Forteau Bay, Labrador.

Corynexochus (*Bonnia*) *busa* Walcott (see pl. 60, figs. 3, 3*a-c*) 326

FIG. 1*a*. (× 10.) Enlargement of surface of specimen figured on pl. 60, fig. 3*a*. U. S. National Museum, Catalogue No. 62774.

Corynexochus capito Walcott 315

FIGS. 2, 2′. (× 2.) Dorsal view and side outline of a convex cranidium. U. S. National Museum, Catalogue No. 62746.

2*a*, 2*a*′. (× 1.5.) Pygidium (and side outline) associated with the specimen represented by fig. 2. U. S. National Museum, Catalogue No. 62747.

The specimens represented by figs. 2, 2*a* occur in a leached calcareous sandstone at locality **48b**, Lower Cambrian: York formation; roadside north of Highland Park, York, Pennsylvania.

2*b*. (× 2.) Cranidium flattened by compression in shaly sandstone. U. S. National Museum, Catalogue No. 15421*a*.

2*c*, 2*d*. (× 2.) Cranidia distorted by lateral compression. U. S. National Museum, Catalogue Nos. 15421*b*, 15421*c*.

2*e*, 2*e*′. (× 2.) Dorsal and side views of a slightly compressed pygidium. U. S. National Museum, Catalogue No. 15421*d*.

The specimens represented by figs. 2*b*, 2*c-e* are illustrated by Walcott on plate 31, figs. 2, 2*a*, 2*b*, Bull. U. S. Geol. Surv., No. 30, 1886, and later as indicated in synonymy of species.

The specimens occur in an impure shaly sandstone at locality **25**, Lower Cambrian: just above Parker's quarry, Georgia, Franklin County, Vermont.

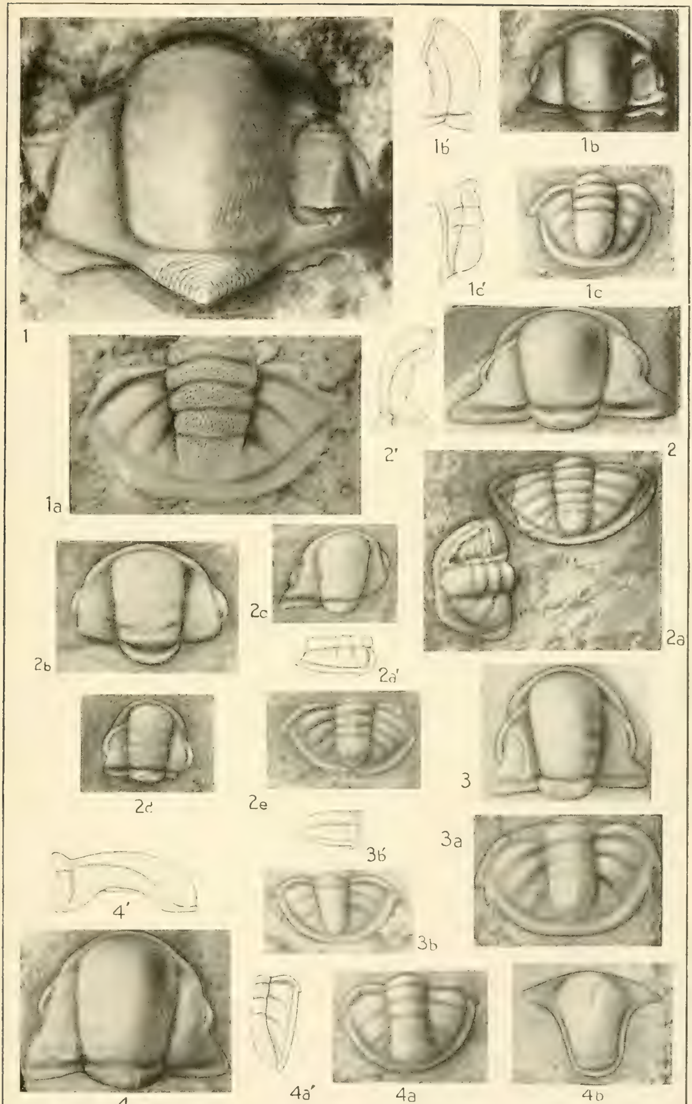
Corynexochus brennus Walcott 314

FIG. 3. (× 4.) Dorsal view of the type specimen of the cranidium. U. S. National Museum, Catalogue No. 62748.

3*a*. (× 2.) A larger pygidium of the same type as that represented by fig. 3*b*. U. S. National Museum, Catalogue No. 62749.

3*b*, 3*b*′. (× 4.) Dorsal view and side outline of a small pygidium associated with the specimens represented by figs. 3, 3*a*. U. S. National Museum, Catalogue No. 62750.

The specimens represented by figs. 3, 3*a-b* are from a limestone boulder of the Bic conglomerate at locality **2 o**, Lower Cambrian: Bic Harbor, Quebec, Canada.



CORYNEXOCHUS

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Corynexochus (*Bonnia*) *fieldensis* (Walcott) 327

FIGS. 4, 4′. (× 3.) Dorsal and side views of the type cranidium. U. S. National Museum, Catalogue No. 62751.

4*a*, 4*a*′. (× 3.) Dorsal and side views of a pygidium associated with the cranidium represented by fig. 5. U. S. National Museum, Catalogue No. 62752.

4*b*. (× 4.) Associated hypostoma. U. S. National Museum, Catalogue No. 62753.

The specimens represented by figs. 4, 4*a*-*b* are from the limestone of locality **35 l**, Lower Cambrian: Ptarmigan Pass, Alberta, Canada.

DESCRIPTION OF PLATE 58

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Asaphiscus wheeleri Meek 390

FIG. 1. (Natural size.) This is the largest entire dorsal shield known to me. It was found by Mr. G. K. Gilbert of the Wheeler Survey. U. S. National Museum, Catalogue No. 62754.

1*a*. (× 2.) Restoration based upon a nearly entire dorsal shield and the specimens represented by figs. 1*b*, 1*c*, 1*d*, 1*f*. U. S. National Museum, Catalogue No. 62755.

1*b*. (× 1.5.) A medium size dorsal shield, somewhat broken by compression in the shale. U. S. National Museum, Catalogue No. 62756.

1*c*. (× 3.) Small dorsal shield with very perfect thorax and pygidium. U. S. National Museum, Catalogue No. 62757.

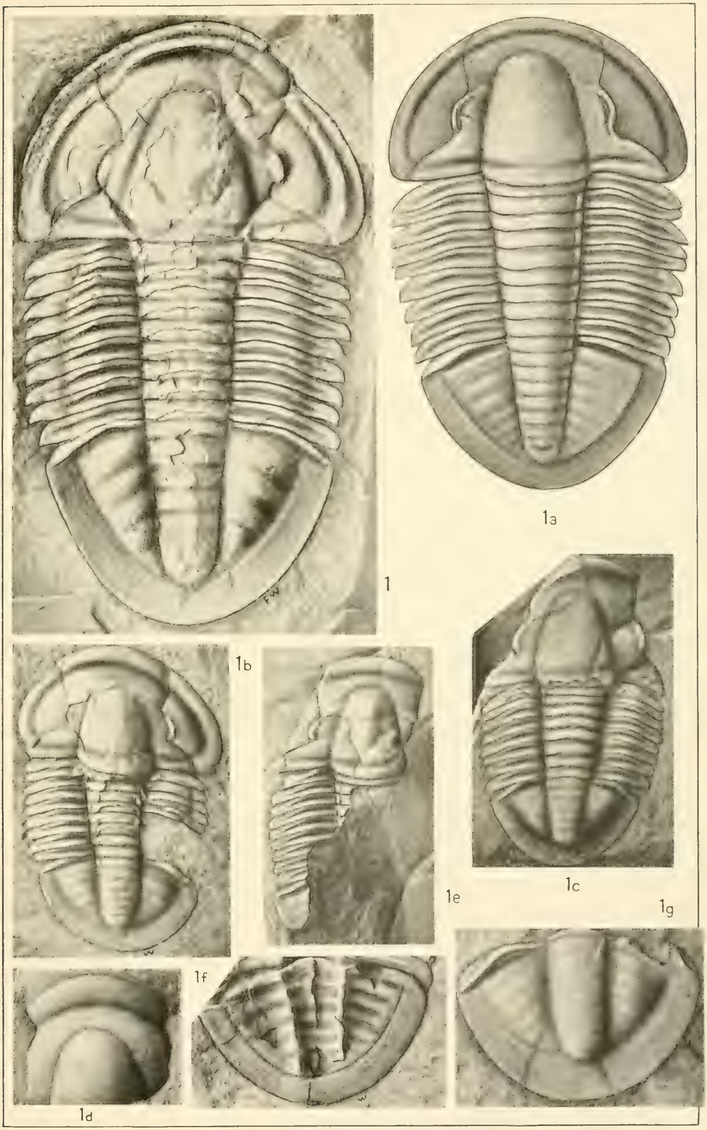
1*d*. (× 2.) Fragment of the anterior half of a cranidium, retaining its original convexity. U. S. National Museum, Catalogue No. 62758.

1*e*. (Natural size.) This is a photograph of one of the type specimens illustrated by fig. 1*c*, plate 2 (Geog. and Geol. Explor. and Surv. west of 100th Merid., 1875, Vol. 4, Pt. 1). U. S. National Museum, Catalogue No. 15460 [=8576].

1*f*. (× 2.) Interior of a pygidium showing very clearly the anchylosed segments of the axis and pleural lobes. U. S. National Museum, Catalogue No. 62759.

1*g*. (× 2.) A convex pygidium, showing characters similar to those of the pygidium of *Dolichometopus productus* (pl. 53, fig. 3). U. S. National Museum, Catalogue No. 62760.

The specimens illustrated by figs. 1, 1*a*-*g*, are from localities **3s** and **4**, Upper Cambrian: Wheeler formation; east of Antelope Springs, House Range, Utah.



CREPICEPHALUS WHEELERI Meek

DESCRIPTION OF PLATE 59

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Asaphiscus iddingsi Walcott 386

FIG. 1. (× 2.) Dorsal shield flattened in argillaceous shale. U. S. National Museum, Catalogue No. 57586.

1*a*. (× 2.) Cranidium, from limestone associated with the shale mentioned under fig. 1. U. S. National Museum, Catalogue No. 58269. (Locality **35r.**)

1*b*. (× 3.) A smaller cranidium, associated with the specimen represented by fig. 1*a*. U. S. National Museum, Catalogue No. 58270.

The specimens represented by figs. 1, 1*a-b*, are from localities **35r** and **36e**: Middle Cambrian; Fu-chóu series; shale interbedded in limestone, Liau-tung, Manchuria.

These figures were published, pl. 23, figs. 1, 1*a-b* (Research in China, Vol. 3, Carnegie Inst. of Washington, Pub. No. 54, Cambrian Faunas of China).

Asaphiscus (?) capella Walcott 385

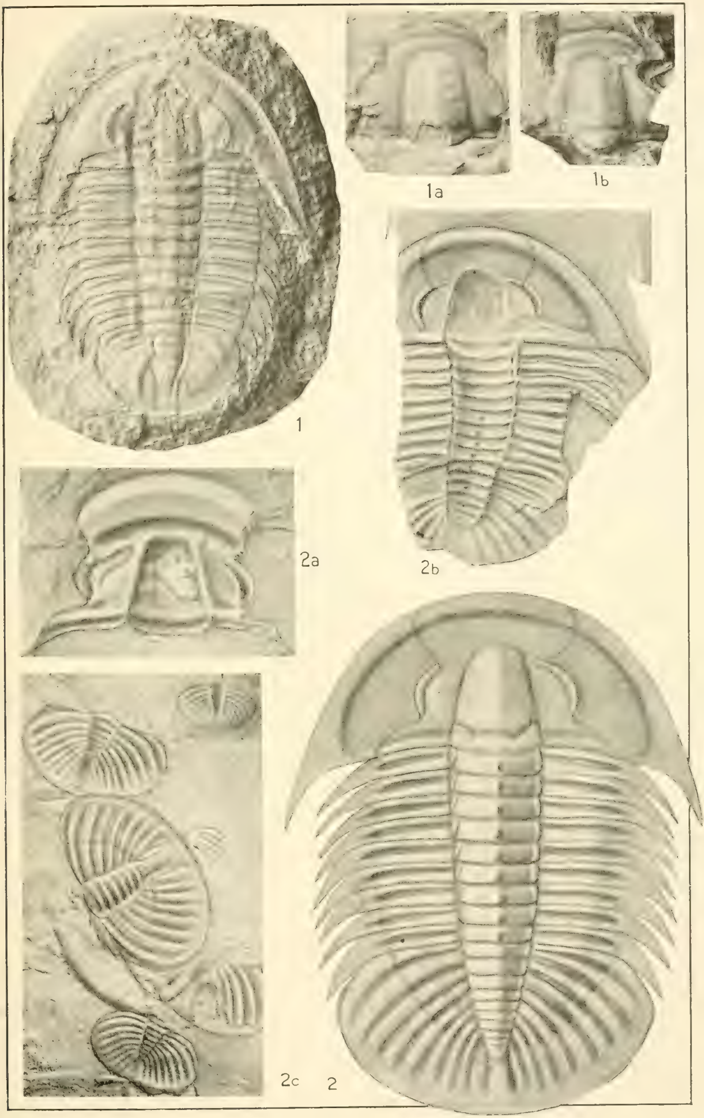
FIG. 2. (× 2.) Restoration based on a nearly entire specimen of the dorsal shield and the specimens represented by figs. 2*a*, 2*b*, 2*c*. U. S. National Museum, Catalogue No. 62761.

2*a*. (× 2.) Cranidium outlining the slightly concave frontal border. U. S. National Museum, Catalogue No. 62762.

2*b*. (Natural size.) Matrix of a crushed and broken dorsal shield, showing wavy doublure of cranidium. U. S. National Museum, Catalogue No. 62763.

2*c*. (Natural size.) Impressions of pygidium in fine-grained shale. U. S. National Museum, Catalogue No. 62764.

The specimens represented by figs. 2, 2*a-c* are from locality **54z**, Middle Cambrian: Wolsey shale; Half Moon Pass, Big Snowy Mountains, Montana.



ASAPHISCUS

DESCRIPTION OF PLATE 60

PAGE

Asaphiscus calenus Walcott 384

FIG. 1. (× 2.) Entire dorsal shield. The right free cheek and frontal limb are restored. U. S. National Museum, Catalogue No. 62765.

1*a*. (× 2.) Interior of a dorsal shield with the right free cheek restored. U. S. National Museum, Catalogue No. 62766.

1*b*. (× 2.) Pygidium and attached thoracic segments. U. S. National Museum, Catalogue No. 62767.

1*c*. (× 2.) A broken cephalon preserving the strong palpebral (ocular) ridge and glabella furrows. U. S. National Museum, Catalogue No. 62768.

The specimens represented by figs. 1, 1*a-c* are compressed in a fine argillaceous shale at locality **5f**, Middle Cambrian: Wolsey shale; 11 miles south of Neihart, in Meagher County, Montana.

Asaphiscus camma Walcott 384

FIG. 2. (× 3.) A small dorsal shield illustrating the character of the species. U. S. National Museum, Catalogue No. 62769.

2*a*. (× 2.) A cranidium preserving strong palpebral ridges. U. S. National Museum, Catalogue No. 62770.

2*b*. (Natural size.) Pygidium. U. S. National Museum, Catalogue No. 62771.

2*c*. (× 4.) Hypostoma associated with this species. U. S. National Museum, Catalogue No. 62772.

The specimens represented by figs. 2, 2*a-c* are compressed in a fine argillaceous shale at locality **4g**, Middle Cambrian: Wolsey shale; 5 miles east-northeast of Logan, Gallatin County, Montana.

Corynexochus (*Bonnia*) *busa* Walcott (see pl. 57, fig. 1*a*) 326

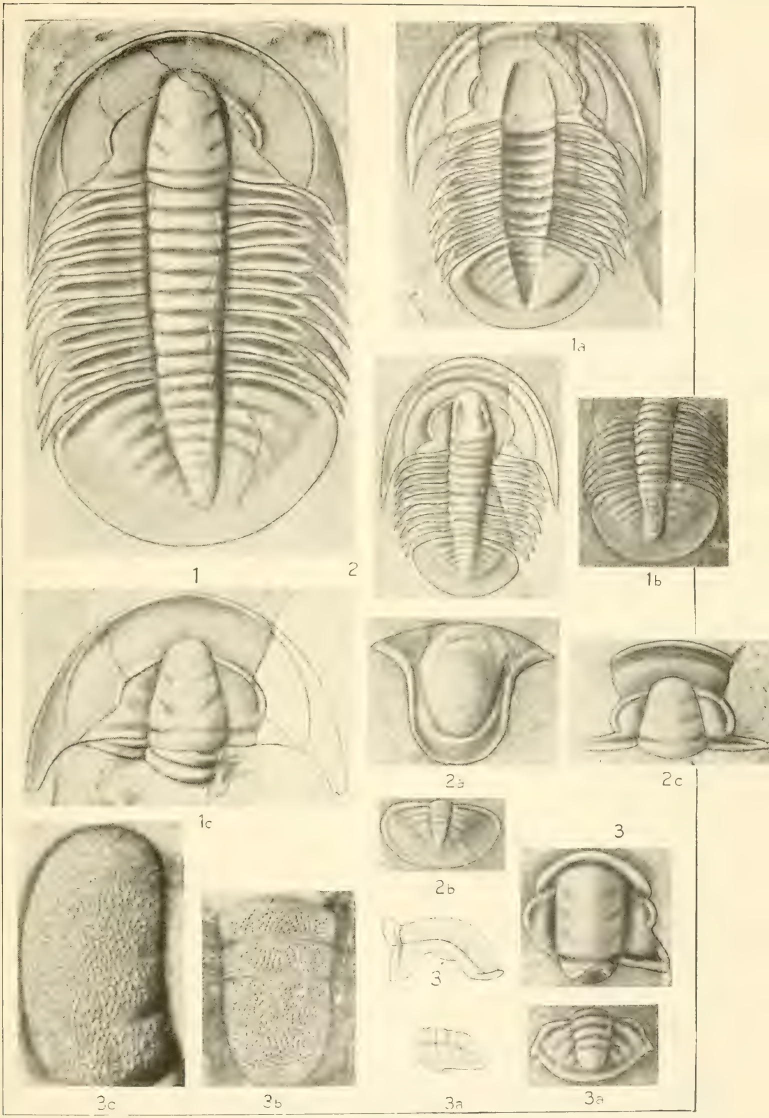
FIGS. 3, 3′. (× 3.) Top and side views of a broken cranidium that retains its convexity. U. S. National Museum, Catalogue No. 62773.

3*a*, 3*a*′. (× 4.) Top and side views of a small, finely preserved pygidium. U. S. National Museum, Catalogue No. 62774.

3*b*. (× 10.) Surface of axial lobe of pygidium of specimen represented by fig. 3*a*.

3*c*. (× 8.) Surface of glabella of specimen represented by fig. 3.

The specimens represented by figs. 6, 6*a-c* occur in a compact gray limestone at locality **2 o**, Lower Cambrian: Bic Harbor, Province of Quebec, Canada.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 61

PAGE

Asaphiscus ? unispinus Walcott 389

FIG. 1. (× 3.) An unusually perfect dorsal shield, partially flattened in shaly limestone. U. S. National Museum, Catalogue No. 62775.

From locality **30n**, Upper Cambrian: Weeks formation; Weeks Canyon, House Range, Utah.

Asaphiscus ? granulatus Walcott 385

FIG. 2. (× 3.) Thorax and pygidium partly crushed in the calcareous shale. U. S. National Museum, Catalogue No. 62776.

2a. (× 2.) Nearly entire dorsal shield, which is the type specimen of the species. U. S. National Museum, Catalogue No. 62777.

The specimens represented by figs. 2 and *2a* are from locality **30n**, Upper Cambrian: Weeks formation; Weeks Canyon, House Range, Utah.

Asaphiscus ? minor Walcott 388

FIG. 3. (× 3.) Very perfect dorsal shield. U. S. National Museum, Catalogue No. 62778.

3a. (× 3.) Interior of a dorsal shield, showing the doublure of the cephalon and pygidium and position of hypostoma. U. S. National Museum, Catalogue No. 62779.

3b. (× 3.) Group of interiors of the dorsal shield, showing hypostoma in place. U. S. National Museum, Catalogue No. 62780.

The specimens represented by figs. 3, *3a-b*, are from locality **30n**, Upper Cambrian: Weeks formation; Weeks Canyon, House Range, Utah.

Blountia mimula Walcott 399

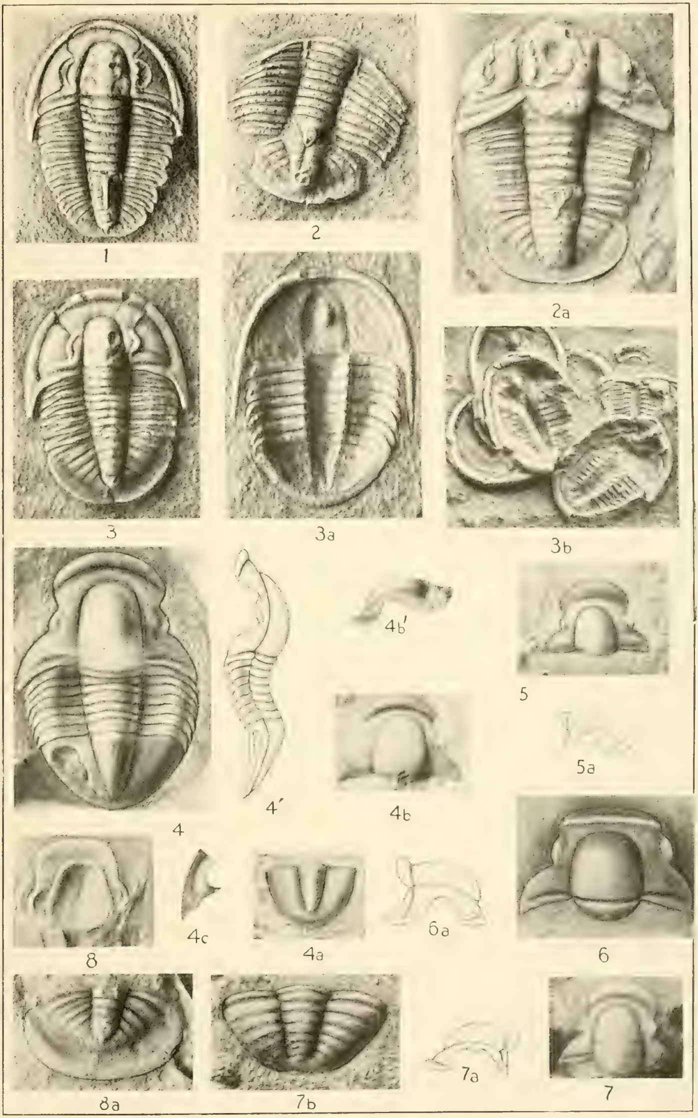
FIGS. 4, 4′. (× 8.) Dorsal and side views of a dorsal shield without the free cheeks. This is the type of the genus *Blountia*. U. S. National Museum, Catalogue No. 62781.

4a. (× 4.) A small pygidium. U. S. National Museum, Catalogue No. 62782.

4b, 4b′. (× 4.) Dorsal and side views of a small cranidium. U. S. National Museum, Catalogue No. 62783.

4c. (× 2.) A free cheek associated with *4b*. U. S. National Museum, Catalogue No. 62784.

The specimen represented by fig. 4 is from locality **120**, Upper Cambrian: Maryville limestone; 2 to 3 miles south of New Market, Jefferson County, and those represented by figs. *4a*, *4b*, and *4c* in same limestone at locality **107c**, 11 miles northwest of Knoxville, both in Tennessee.



CAMBRIAN TRILOBITES

PAGE

Blountia alexas Walcott 398

FIGS. 5, 5*a*. (× 3.) Dorsal and side views of the type cranidium. U. S. National Museum, Catalogue No. 62785.

The specimen represented by fig. 5 is from locality **125**, Upper Cambrian: Maryville limestone; 4 miles northeast of Rogersville, Hawkins County, Tennessee.

Blountia ? alemon Walcott 397

FIGS. 6, 6*a*. (× 5.) Dorsal and side views of the type cranidium. U. S. National Museum, Catalogue No. 62786.

The specimen represented by fig. 6 is from locality **119**, Upper Cambrian: Maryville limestone; 1.5 miles southeast of Morristown, Hamblen County, Tennessee.

Blountia anser Walcott 399

FIGS. 7, 7*a*. (× 5.) Dorsal view and side outline of type cranidium. U. S. National Museum, Catalogue No. 62787.

7*b*. (× 5.) Pygidium associated with cranidium represented by fig. 7. U. S. National Museum, Catalogue No. 62788.

The specimens represented by figs. 7, 7*b* are from locality **120**, Upper Cambrian: Maryville limestone; 2 to 3 miles south of New Market, Jefferson County, Tennessee.

Asaphiscus calanus Walcott 384

FIG. 8. (Natural size.) Cast of interior of a broken cranidium. U. S. National Museum, Catalogue No. 62789.

8*a*. (Natural size.) Pygidium associated with the cranidium represented by fig. 8. U. S. National Museum, Catalogue No. 62790.

The specimens represented by figs. 8, 8*a* are from a fine shaly sandstone at locality **47h**, Middle Cambrian: Wolf Creek, 6 miles below Rocky Gap, Bland County, Virginia.

DESCRIPTION OF PLATE 62

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Asaphiscus (*Blainia*) *gregarius* Walcott 394

FIG. 1. (× 2.) Dorsal views of a small, imperfect dorsal shield that has a convex cranidium. U. S. National Museum, Catalogue No. 62791.

1*a*, 1*a'*. (Natural size.) Dorsal and side views of a dorsal shield with a well-preserved pygidium. The free cheeks are restored from another specimen. U. S. National Museum, Catalogue No. 62792.

1*b*. (Natural size.) Dorsal view of a somewhat broken up dorsal shield. U. S. National Museum, Catalogue No. 62793.

1*b'*. (Natural size.) Side view of a broken dorsal shield, showing the profile of the cranidium. U. S. National Museum, Catalogue No. 62794.

1*c*, 1*c'*. (× 4.) Associated hypostoma and side outline. U. S. National Museum, Catalogue No. 62795.

1*d*, 1*d'*. (Natural size.) Dorsal and side views of a finely preserved pygidium. U. S. National Museum, Catalogue No. 62796.

1*e*. (× 3.) A small dorsal shield partially concealed in the matrix; the covered parts are restored in outline. U. S. National Museum, Catalogue No. 62797.

1*f*. (× 2.) Interior of a smaller pygidium with a broad, striated doublure. U. S. National Museum, Catalogue No. 62798.

1*g*, 1*g'*. (Natural size.) Dorsal and side views of a finely preserved pygidium. U. S. National Museum, Catalogue No. 62799.

1*h*. (× 2.) An enrolled dorsal shield. U. S. National Museum, Catalogue No. 62800.

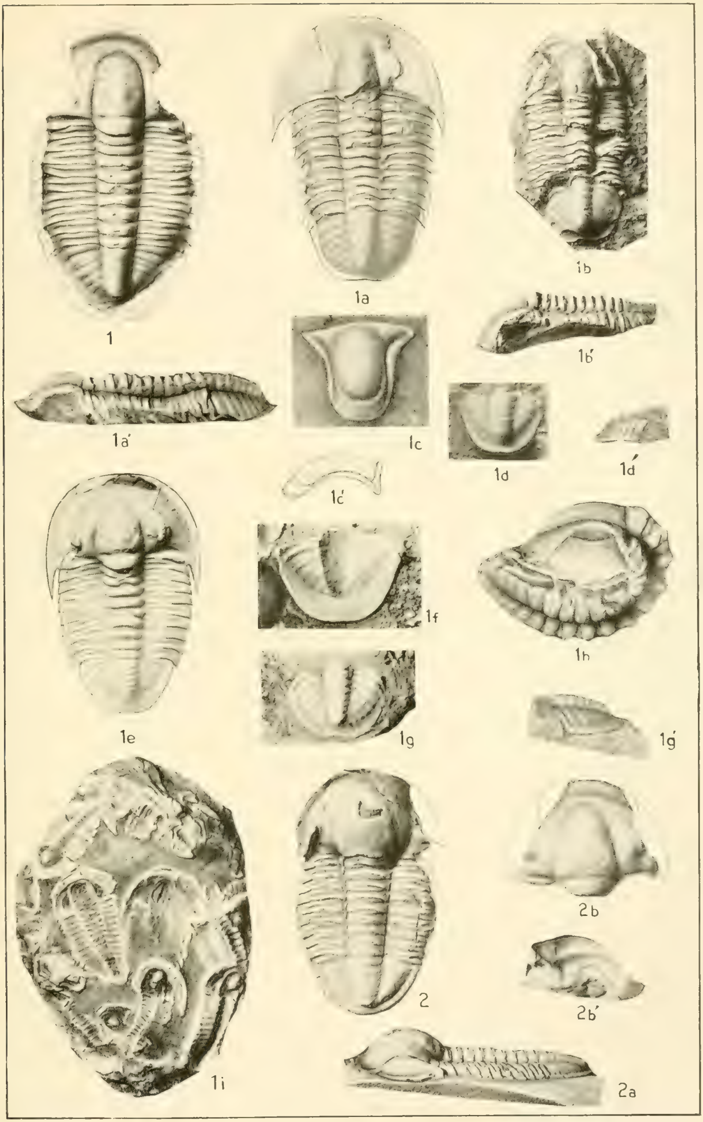
1*i*. (Natural size.) A group of small dorsal shields adhering to the surface of a siliceous concretion. U. S. National Museum, Catalogue No. 62801.

Asaphiscus (*Blainia*) *paula* Walcott 395

FIGS. 2, 2*a*. (Natural size.) Dorsal and side views of an almost entire dorsal shield. U. S. National Museum, Catalogue No. 62802.

2*b*, 2*b'*. (Natural size.) Dorsal and side views of a fine cranidium. U. S. National Museum, Catalogue No. 62803.

The specimens represented by figs. 1, 1*a-i*, 2, 2*a-b* are attached to the outer surface of siliceous nodules that are embedded in a dark argillaceous shale of the lower Conasauga formation: Middle Cambrian; (**90x**) 3 miles east of Center, near Blaine, Cherokee County, Alabama.



ASAPHISCUS (BLAINIA)

DESCRIPTION OF PLATE 63

FIGS. 1, 1*a*. (× 1.5.) Dorsal and side views of a convex cranidium. U. S. National Museum, Catalogue No. 62804.

1*b*, 1*b′*. (Natural size.) Dorsal and side views of a large, partially exfoliated pygidium. U. S. National Museum, Catalogue No. 62805.

1*c*, 1*c′*. (× 3.) Dorsal and side views of a small pygidium. U. S. National Museum, Catalogue No. 62806.

1*d*, 1*d′*. (× 2.) Dorsal and side views of a natural cast of the interior of the test of a pygidium. U. S. National Museum, Catalogue No. 62807.

1*e*. (Natural size.) Fragment of a thoracic segment. U. S. National Museum, Catalogue No. 62808.

The specimens represented by figs. 1, 1*a*-*e* were associated in a block of the Maryville limestone at locality **107x**, Upper Cambrian: 11 miles northwest of Knoxville, Tennessee.

FIGS. 2, 2*a*. (× 2.) Dorsal view and side outline of a broken cranidium. U. S. National Museum, Catalogue No. 62809.

The specimen represented by fig. 2 is from locality **119**, Upper Cambrian: Maryville limestone; 1.5 miles southeast of Morristown, Hamblen County, Tennessee.

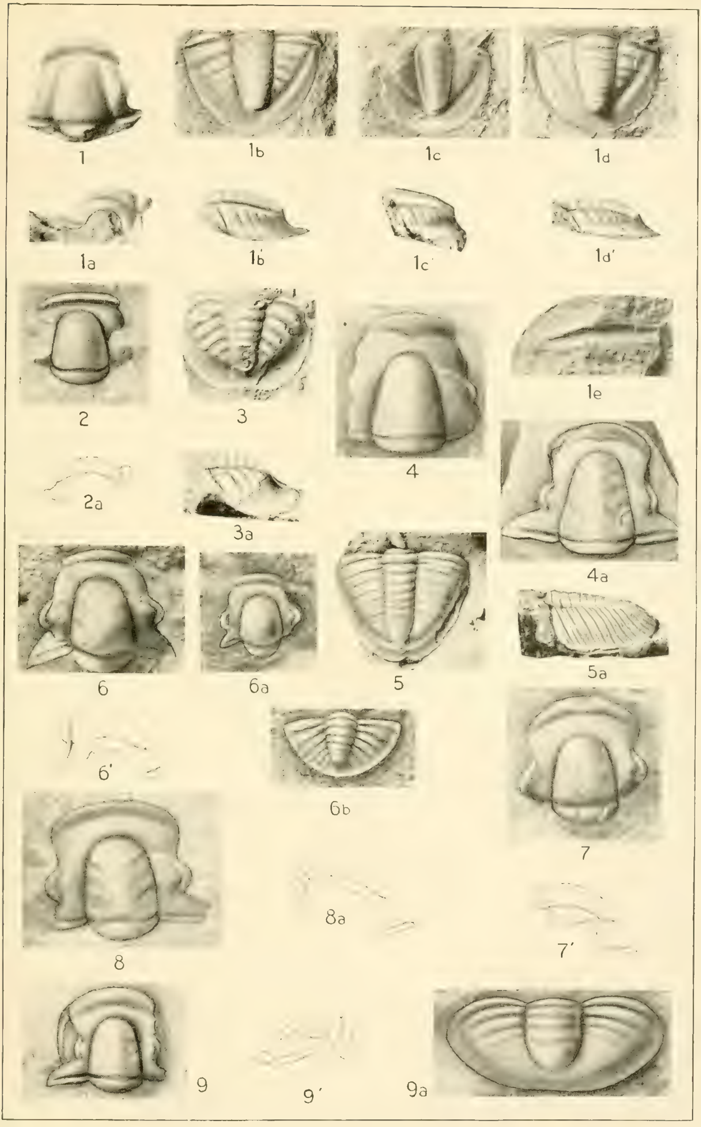
FIGS. 3, 3*a*. (Natural size.) Dorsal and side views of pygidium. U. S. National Museum, Catalogue No. 62810. From locality **119**, see fig. 2.

FIG. 4. (Natural size.) Dorsal view of the type cranidium. U. S. National Museum, Catalogue No. 62811.

4*a*. (Natural size.) A nearly entire cranidium. U. S. National Museum, Catalogue No. 62812.

5, 5*a*. (Natural size.) Dorsal and side views of a large pygidium associated with the specimens represented by figs. 4, 4*a*. U. S. National Museum, Catalogue No. 62813.

The specimens represented by figs. 4, 4*a*, 5, 5*a* are attached to the outer surface of siliceous nodules that are embedded in a dark argillaceous shale of the lower Conasauga formation: Middle Cambrian: (**90x**) 3 miles east of Center, near Blaine, Cherokee County, Alabama.



ASAPHISCUS

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Asaphiscus ? florus Walcott 392

FIGS. 6, 6′. (× 5.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62814.

6*a*. (× 5.) A small cranidium without glabellar furrows. U. S. National Museum, Catalogue No. 62815.

6*b*. (× 2.) An associated pygidium. U. S. National Museum, Catalogue No. 62816.

The specimens represented by figs. 6, 6*a-b* are from locality **107g**, Upper Cambrian ?: Kittatinny ? limestone at Drab, Blair County, Pennsylvania.

Asaphiscus ? cf. *florus* Walcott 393

FIG. 7. (× 4.) Dorsal view and side outline of cranidium. U. S. National Museum, Catalogue No. 62817.

The specimen represented by fig. 7 is from locality **107e**, Upper Cambrian ?: Kittatinny ? limestone; southwest of Ore Hill, 4 miles south of Roaring Spring, Bedford County, Pennsylvania.

Asaphiscus ? duris Walcott 392

FIGS. 8, 8*a*. (× 3.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62818.

The specimen represented by fig. 8 is from locality **107f**, Upper Cambrian ?: 2 miles north of Bakers Summit, Bedford County, Pennsylvania.

Asaphiscus ? agatho Walcott 391

FIGS. 9, 9′. (× 4.) Dorsal view and side outline of type cranidium. U. S. National Museum, Catalogue No. 62819.

9*a*. (× 4.) Pygidium associated in same piece of limestone with cranidium represented by fig. 9. U. S. National Museum, Catalogue No. 62820.

The specimen represented by figs. 9, 9*a* is from locality **123a**, Maryville limestone; 4 miles northeast of Rogersville, Hawkins County, Tennessee.

DESCRIPTION OF PLATE 64

FIGS. 1, 1*a*. (× 2.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62821.

1*b*, 1*b′*. (× 2.) Pygidium and side outline associated with the cranidium represented by fig. 1. U. S. National Museum, Catalogue No. 62822.

1*c*. Natural size view of 1*b*.

The specimens represented are from locality **123b**, Upper Cambrian: Maryville limestone; Rogersville, Hawkins County, Tennessee.

FIGS. 2, 2′. (× 3.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62823.

The specimen represented is from locality **102a**, Upper Cambrian: Maryville limestone; 1.25 miles east of Rogersville, Hawkins County, Tennessee.

FIGS. 3, 3′. (× 4.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62824.

3*a*. (× 2.) Pygidium associated with the cranidium represented by fig. 3. U. S. National Museum, Catalogue No. 62825.

The specimens represented are from locality **107**, Upper Cambrian: Conasauga formation (Maryville limestone); 11 miles northwest of Knoxville, Tennessee.

FIGS. 4, 4′. (× 2.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62826.

4*a*, 4*a′*. (Natural size.) Dorsal view and side outline of pygidium associated with the cranidium fig. 4. U. S. National Museum, Catalogue No. 62827.

4*b*. Natural size view of fig. 4.

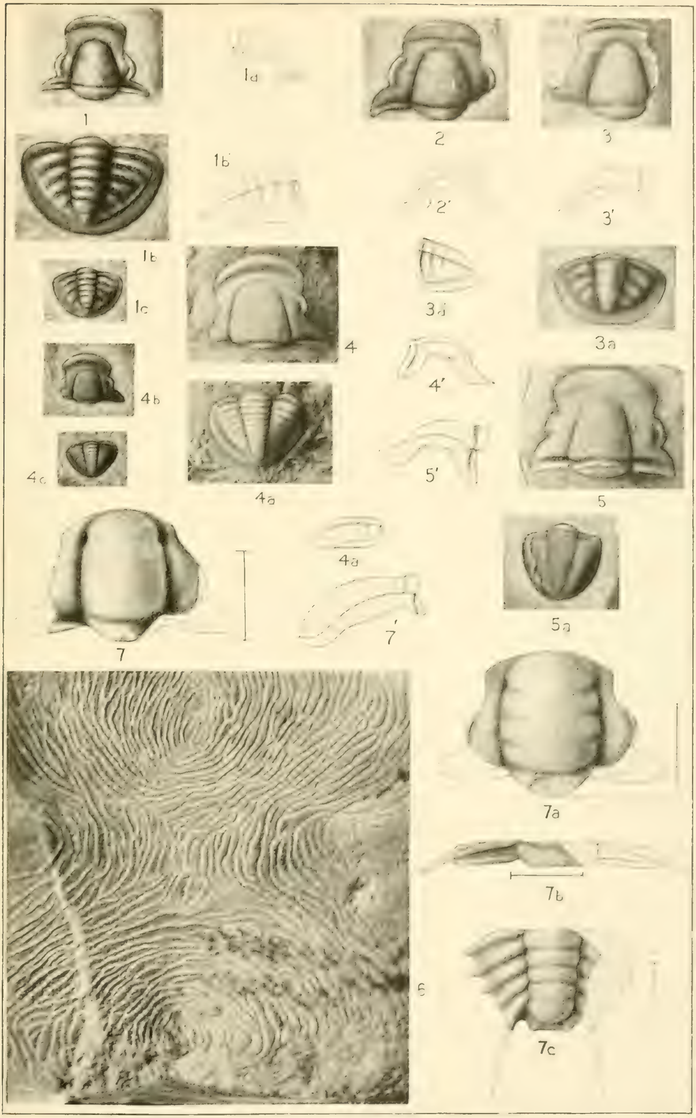
4*c*. (Natural size.) A small pygidium. U. S. National Museum, Catalogue No. 62828.

The specimens represented are from locality **123b**, Upper Cambrian: Maryville limestone; Rogersville, Tennessee.

FIGS. 5, 5′. (× 1.5.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62829.

5*a*. (Natural size.) Pygidium associated with the cranidium fig. 5. U. S. National Museum, Catalogue No. 62830.

The specimens represented are from locality **120**, Upper Cambrian: Maryville limestone; north of Bays Mountain, 2 to 3 miles south of New Market, Jefferson County, and 18 miles east-northeast of Knoxville, Tennessee.



CAMBRIAN TRILOBITES

PAGE

Corynexochus (*Bonnia*) *parvulus* (Billings). (See plate 57.) 328

FIG. 6. (× 8.) Enlargement of the surface of the occipital ring and posterior portion of the glabella. U. S. National Museum, Catalogue No. 62744.

(Note description and locality from plate 57, fig. 1*b*.)

Dorypyge richthofeni Dames 328

FIG. 7. (× 1.5.) Cranidium with finely granulated surface and side outline. From locality **C1**, Middle Cambrian: Kiu-lung group; south of Yen-chuang, Shan-tung. U. S. National Museum, Catalogue No. 57876.

7a. (× 1.5.) Central parts of a cephalon showing glabellar furrows and coarse granulations. From locality **C19**, Middle Cambrian: Ch'ang-hia limestone at Ch'ang-hia, Shan-tung. U. S. National Museum, Catalogue No. 57878.

7b. (× 2.) Thoracic segment showing straight pleural groove. From locality **C29**, Middle Cambrian: Ch'ang-hia limestone; west of Ch'ang-hia, Shan-tung. U. S. National Museum, Catalogue No. 57881.

7c. (× 1.5.) Top and side views of pygidium associated with 6*a*. (**C19**) U. S. National Museum, Catalogue No. 57879.

The above figures are reproduced from plate 8, figs. 1, 1*a*, 1*d* and 1*c*, respectively, Research in China, Vol. 3, Cambrian Faunas of China, 1913, Carnegie Inst. of Washington.

DESCRIPTION OF PLATE 65

FIG. 1. (Natural size.) Broken cranidium. U. S. National Museum, Catalogue No. 62831.

1a, 1b. (× 2.) Free cheeks associated with the cranidium fig. 1. U. S. National Museum, Catalogue Nos. 62832, 62833.

1c. (Natural size.) Associated thoracic segment. U. S. National Museum, Catalogue No. 62834.

1d. (× 2.) Distorted pygidium. U. S. National Museum, Catalogue No. 62835.

1e. (Natural size.) Pygidium with the posterior segment of the thorax attached. U. S. National Museum, Catalogue No. 62836.

The specimens represented by figs. 1, *1a-d* are from locality **30y** (=**30l**), Upper Cambrian: Orr formation; on Orr Ridge, about 5 miles south of Marjum Pass, House Range, Millard County, Utah.

FIGS. 2, 2′. (× 4.) Dorsal and side view of the type cranidium. U. S. National Museum, Catalogue No. 62837.

2a, 2a′. (× 5.) Pygidium associated with the cranidium of fig. 2. U. S. National Museum, Catalogue No. 62838.

The specimens represented by figs. 2, *2a* are from locality **11 o,** Middle Cambrian: Marjum formation; 4 miles southeast of Antelope Springs, House Range, Utah.

FIG. 3. (× 1.5.) Dorsal view and side outline of the type cranidium. U. S. National Museum, Catalogue No. 62839.

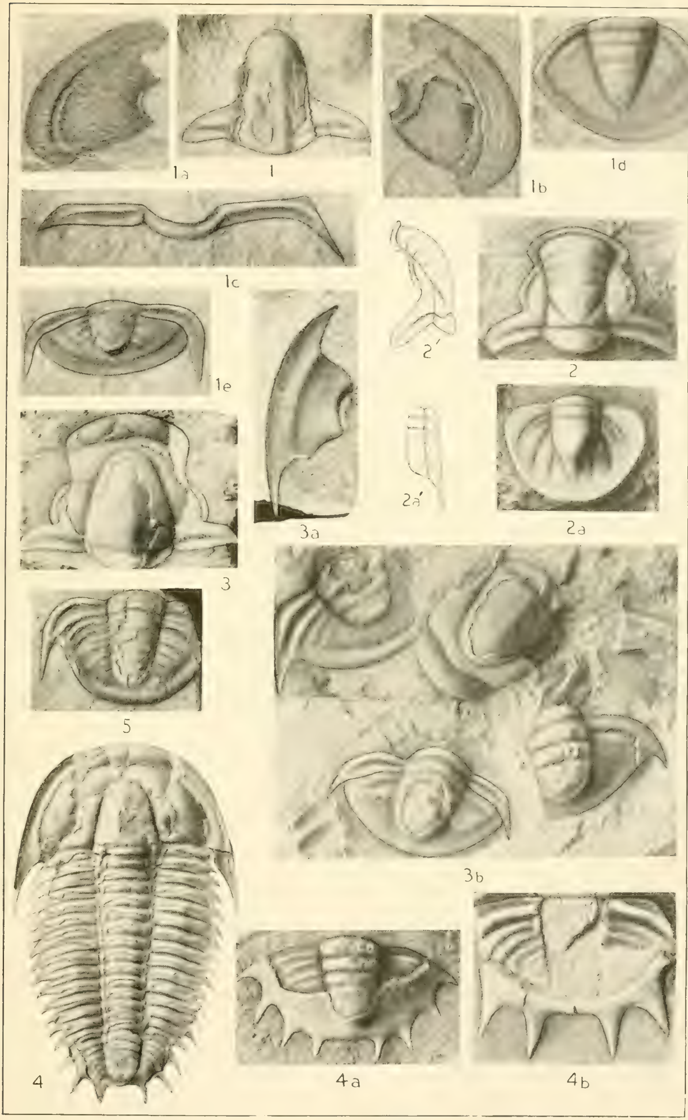
3a. (× 3.) Free cheek associated with cranidium fig. 3. U. S. National Museum, Catalogue No. 62840.

3b. (× 3.) Group of three pygidia and one broken cranidium. U. S. National Museum, Catalogue No. 62841.

The specimens represented by figs. 3, *3a-b* are from locality **31r,** Middle Cambrian: Marjum formation; 1 mile southeast of Marjum Pass, House Range, Utah.

FIG. 4. (Natural size.) Entire dorsal shield. The type of the species. U. S. National Museum, Catalogue No. 62842.

4a. (× 3.) Pygidium with test partly exfoliated. U. S. National Museum, Catalogue No. 62843.



CAMBRIAN TRILOBITES

Marjumia typa Walcott—Continued. PAGE

4*b*. (× 2.) Under side of a pygidium showing doublure and four spines. U. S. National Museum, Catalogue No. 62844.

The specimens represented by figs. 4, 4*a-b* are from locality **11q**, Middle Cambrian: Marjum formation; hard calcareous shales, 2.5 miles east of Antelope Springs, Millard County, Utah.

Bathyuriscus ? sp. undt. (2) 348

FIG. 5. (Natural size.) Pygidium with a single antero-lateral spine, as in *Marjumia callas*, fig. 3b. U. S. National Museum, Catalogue No. 62845.

The specimen represented is from locality **11p**, Middle Cambrian: Marjum formation; 2.5 miles southeast of Marjum Pass, House Range, Utah.

DESCRIPTION OF PLATE 66

FIG. 1. (Natural size.) Large, nearly perfect, compressed specimen of the dorsal shield. U. S. National Museum, Catalogue No. 62846.

This figure is the same as that on plate 4, fig. 4, Canadian Alpine Journal [Vol. 1, 1908].

1*a*. (Natural size.) Outline of a small specimen illustrating the proportionally smaller pygidium. U. S. National Museum, Catalogue No. 62847.

1*b*. (Natural size.) An hypostoma, associated with figs. 1 and 1*a*. U. S. National Museum, Catalogue No. 62848.

The specimens represented by figs. 1, 1*a-b* are from locality **14s**, Middle Cambrian: Stephen formation; Mount Stephen, British Columbia, Canada.

FIG. 2. (Natural size.) Dorsal shield and the type specimen of the genus and species. The free cheeks have been restored from other specimens. U. S. National Museum, Catalogue No. 62849.

2*a*, 2*a'*, 2*b*, 2*b'*. Natural size and enlarged figures of free cheeks, associated in the same rock with the specimen represented by fig. 2. U. S. National Museum, Catalogue Nos. 62850, 62851.

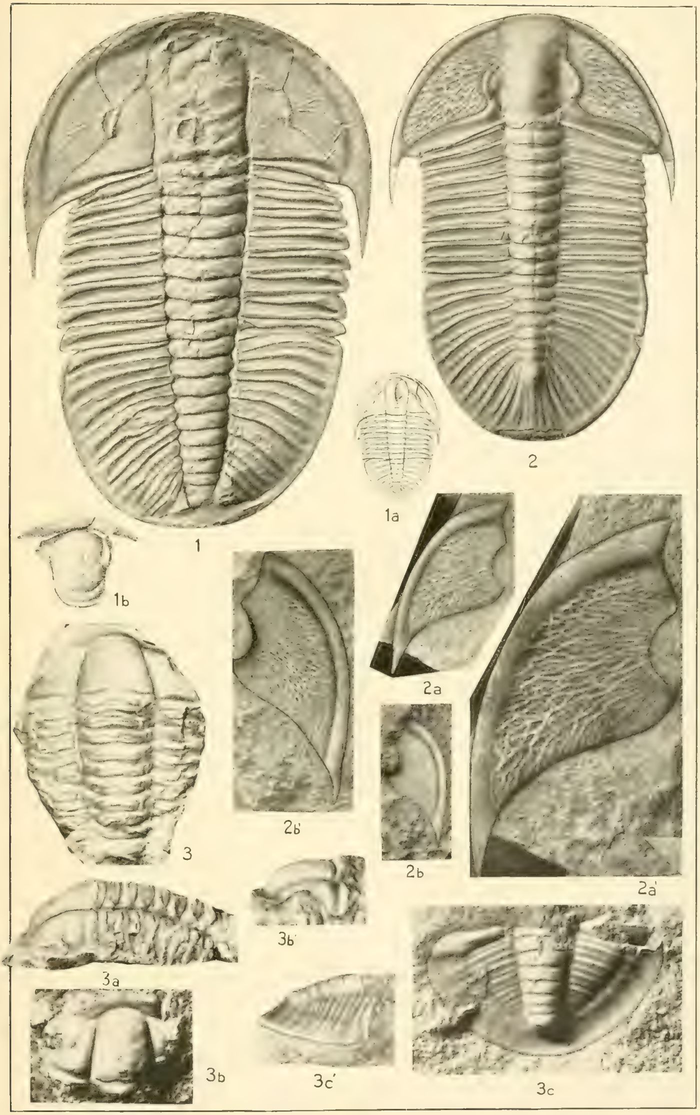
The specimens represented by figs. 2, 2*a-b* are from locality **11q**, Middle Cambrian: Marjum formation; hard calcareous shales, 2.5 miles east of Antelope Springs, Millard County, Utah.

FIGS. 3, 3*a*. (Natural size.) Dorsal and side views of broken cranidium with portions of nine thoracic segments attached. This is the type specimen of the species. U. S. National Museum, Catalogue No. 62852.

3*b*, 3*b'*. (× 4.) Dorsal and side views of a small cranidium. U. S. National Museum, Catalogue No. 62853.

3*c*, 3*c'*. (× 4.) Dorsal and side views of a small associated pygidium enlarged to show the segmentation of the axis and pleural lobes. U. S. National Museum, Catalogue No. 62854.

The specimens represented by figs. 3, 3*a-c* are from locality **118a**, Upper Cambrian: Maryville limestone; 1.5 miles south of Greeneville, Greene County, Tennessee.



CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 67

PAGE

Pagetia bootes Walcott 408

FIG. 1. (× 8.) Specimen showing palpebral ridge, eye lobe and facial suture on right side, occipital spine and caudal spine which is partially turned over so as to indicate that it is slightly angular on the upper side. U. S. National Museum, Catalogue No. 62855.

1a. (× 8.) Specimen with palpebral ridge, traces of two pairs of short glabellar furrows, right eye and facial suture. U. S. National Museum, Catalogue No. 62856.

1b. (× 8.) Dorsal shield with free cheeks displaced. U. S. National Museum, Catalogue No. 62857.

1c. (× 8.) A broken cephalon with glabella and a large occipital spine that is as long, if not longer than the glabella. U. S. National Museum, Catalogue No. 62858.

1d. (× 8.) Dorsal shield with the right free cheek and eye detached from the fixed cheek. U. S. National Museum, Catalogue No. 62859.

1e. (× 8.) A fine dorsal shield with the palpebral ridges, facial suture on right side, and base of caudal spine. U. S. National Museum, Catalogue No. 62860.

1e′. (× 8.) Side outline view based on the specimens represented by figs. 1 and *1e*.

1f. (× 8.) Matrix of a dorsal shield from which the free cheeks have been displaced. This specimen is on the same piece of shale as that represented by fig. *1c*. U. S. National Museum, Catalogue No. 62861.

The specimens represented by figs. 1, *1a-f* are from locality **35k**, Middle Cambrian: Burgess shale; Burgess Pass, British Columbia, Canada.

Pagetia clytia Walcott 408

FIG. 2. (× 10.) Two specimens of the dorsal shield with the lower one preserving the free cheeks and elevated palpebral lobes. U. S. National Museum, Catalogue No. 62862.

2a. (× 10.) Cephalon with palpebral lobes and free cheeks displaced or crushed down in the soft shale. U. S. National Museum, Catalogue No. 62863.

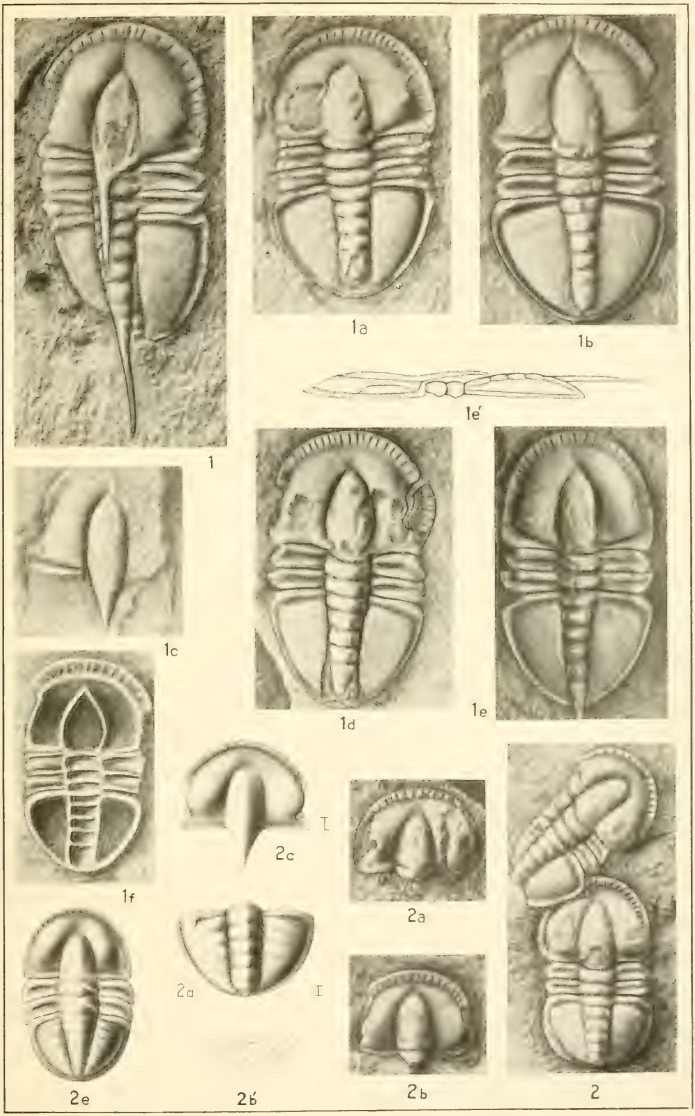
2b. (× 10.) Dorsal view and side outline of a cephalon with base of occipital spine, slight traces of glabellar furrows, left side palpebral lobe and faint trace of palpebral ridge; free cheeks displaced. U. S. National Museum, Catalogue No. 62864.

2c. (× 11.) Wash drawing based on photograph of a cephalon with free cheeks displaced. U. S. National Museum, Catalogue No. 62865.

2d. (× 11.) Wash drawing based on photograph of a pygidium. U. S. National Museum, Catalogue No. 62866.

2e. (× 11.) Wash drawing based on a photograph of a dorsal shield. The eyes and facial sutures are too diagrammatic. This drawing was made in 1907 before the discovery of *Pagetia bootes* in 1909. U. S. National Museum, Catalogue No. 62867.

The specimens represented by figs. 2, *2a-e* are from locality **55c**, Middle Cambrian: Spence shale; 15 miles (24.2 km.) west of Montpelier, Idaho.



PAGETIA

INDEX

The references in **heavy-faced** type refer to the locality numbers and the pages upon which the genera and species are described and figured.